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THE CONSUMPTION OF WATER IN MUNICIPAL SUPPLIES AND THE RESTRICTION OF WASTE.

An Informal Discussion at the Annual Convention, July 27th, 1901.

SUBJECT FOR DISCUSSION:

"The Consumption of Water in Municipal Supplies and the Restriction of Waste."

By Messrs. EMIL KUICHLING, GARDNER S. WILLIAMS, JOHN C. TRAUTWINE, JR., RUDOLPH HERING, DESMOND FITZGERALD, JAMES OWEN, D. C. HUMPHREYS, J. P. A. MAIGNEN, J. N. CHESTER, OBERLIN SMITH, J. H. HARLOW, CLEMENS HERSCHEL, FRED. BROOKS, DEXTER BRACKETT, G. L. CHRISTIAN, FOSTER CROWELL, CHARLES W. SHERMAN and EMIL KUICHLING.

E. KUICHLING, M. Am. Soc. C. E.—This topic is apparently old and hackneyed, but, in consequence of the rapid increase of our urban population, the exhaustion or growing pollution of conveniently situated sources of water supply, and the greatly augmented costs of securing additional supplies of irreproachable quality, the questions of consumption and waste of water often become paramount economic issues in our large cities, and their intelligent discussion in scientific societies from time to time is sure to be of interest not only to the members, but also to the public. New points of view are likewise de- Mr. Kuichling.

Mr. Kuichling. veloping, with greater experience and study, whereby convictions or opinions which were formerly regarded as well founded may now be modified or changed; and, as many of our members have doubtless accumulated valuable data relating to the topic since it was last formally debated by them, it is earnestly hoped that they will kindly present the same on this occasion.

As the sharp definition of the terms used greatly facilitates the consideration of any subject, it becomes desirable for each speaker to state as clearly as possible what he understands or includes in the expressions "consumption" and "waste." This is very necessary, inasmuch as certain items of consumption may fairly be regarded as legitimate use in one case, and unjustifiable waste in another. Ample evidence of this fact is afforded by the perusal of many old and new papers on the subject of waste prevention. Usually, waste is associated almost exclusively with the supply to families, and little is said about the quantity taken by manufacturers in various branches of industry. This may be due to following inferences drawn from European cities, where much of the water used in manufacturing is obtained from private sources, or it may arise from the circumstance that the service pipes for domestic uses greatly outnumber those for industrial purposes, and, by the multiplicity of household fixtures and faucets, afford a greater opportunity for waste. On the other hand, it is often the case that a single manufacturing establishment will consume daily more water than is required for the domestic uses of hundreds or even thousands of people, and little attention is given to the question whether a large percentage of such water is not wasted.

Inquiries of the latter kind are rarely encountered, as it is presumed that all manufacturers are served by meter and will voluntarily seek to reduce their water consumption to the lowest practicable limit. The observations of the speaker, however, lead him to the conclusion that this view is erroneous, and that in many industries a great reduction in the quantity taken from the public water supply can readily be effected at comparatively small cost to the consumer. Especially was this true in places where the water rates were relatively high, and a private supply of suitable quality for manufacturing purposes could be obtained from wells or conveniently located streams, with considerably less annual expense than was incurred for the use of the public supply. The chief objection of manufacturers to such private water plants is their initial cost and the trouble of intelligent supervision; but if the consumer can be assured of some assistance in the latter direction from the officer in charge of the public water-works, much of the difficulty will be surmounted, and an existing costly potable supply can be conserved for a considerably longer period of time than would otherwise be possible.

The terms "consumption" and "waste" accordingly need sharp

Mr. Kuichling.

definition. By the former, the total quantity of water taken from the source is commonly understood, and hence it becomes subject to various losses of transit and storage, as well as to inaccuracies of original estimation or measurement. Where pumping engines are used as meters, large differences are often found between the actual delivery and that which is computed from the number of strokes made by the pistons or plungers. Similarly, in the case of gravity supplies, the discharge of aqueducts or pipe conduits is frequently much less some years after the completion of the works than it was at the outset; and in both cases notable variations of discharge may occur at different seasons of the same year, independently of possible leakage in transit. The loss from storage and distributing reservoirs is likewise of importance, as well as the leakage of the system of distributing pipes, stop-valves and fire-hydrants. The sum of these items is often a large proportion of the assumed or estimated total quantity taken from the source before the water reaches the consumers, and should properly be deducted before computing the consumption. In the cases where such deduction is made care should be taken to note the fact.

The term "waste," on the other hand, is frequently applied to all water consumed beyond a certain *per capita* quantity, which is generally determined by a more or less arbitrary comparison of the consumption in a number of communities, regardless of whether similar conditions prevail therein, and also of the quantity last in transit from the source to the consumer. Strictly speaking, however, waste should be considered only as the excess above legitimate or reasonable use, and this definition at once opens up a wide range for debate, since that which is looked upon as reasonable use in one place may be treated as waste in another. The public policy of the community, with respect to manufacturers, as well as the economical maintenance of the water pipes and fittings in buildings, are therefore factors which can fairly be taken into account, along with the cost of obtaining the required supply. In other words, a system of public water-works may sometimes be regarded as a means of promoting the rapid growth of a community, and adding largely to its wealth by making it a desirable manufacturing center, instead of being treated only as a sanitary necessity and a means for extinguishing fires. The definition of "waste" thus depends greatly on the point of view, and this in turn is largely influenced by the cost of obtaining or increasing the supply.

If a city is so situated that the expense of securing an abundance of potable water is relatively great, the legitimate uses of the supply and the restriction of waste should obviously receive the most careful consideration. In such cases, it becomes important to know what limits can fairly be placed on the domestic consumption in order to leave as much as possible for industrial uses; and, similarly, a

Mr. Kuichling. knowledge of the necessities of the various industries is required in order to prevent the abuse of an existing or projected system of works. The same is also true where the available sources of supply are of limited magnitude, as is the case with the great majority of cities. Relatively few of the large cities of Christendom are so located as to command access to practically boundless quantities of fresh water of proper degree of purity, or are so wealthy as to be able to incur the cost of conveying such water from very great distances. Lavishness of consumption is therefore an evil in most cases, and the arguments or means for abating it, as far as practicable and reasonable, deserve the widest publicity. As was tersely stated in an able paper* on this subject by the late Charles B. Brush, M. Am. Soc. C. E., presented thirteen years ago:

"The amount of water that can be used is limited; the amount that can be wasted has no limit. * * * The * * * attempt of cities and towns to increase their water supply plant to keep pace with their waste is a hopeless task. It amounts to the same thing as trying to fill a pail which has only a sieve for a bottom."

The usual prescription for the water-works authorities of a city or town wherein an excessive consumption occurs is to apply meters on every service pipe. This treatment implies that the water which is sold by measure is not wasted or used unnecessarily, and that the economical instinct of each consumer is aroused and maintained in activity by the knowledge that the meter keeps a true record of all the water drawn on his premises. It sometimes happens, however, that the same instinct leads to positive waste when the cost of preventing such unnecessary draft is greater than the value of the water; and it follows that in order to protect the works from abuse, the consumer should be compelled to place his water appliances in such condition as to prevent waste, notwithstanding his entire willingness to pay for the water drawn by him. The application of a meter, therefore, is not sufficient in such cases, as it must be supplemented by the establishment of a measure of reasonable use.

An instructive instance of this kind is afforded by the occurrence of severe cold in many of our Northern cities. On such occasions it is the practice to allow some water to run to waste during the night, in unheated rooms or premises, in order to prevent the service pipes from freezing, and during this period the aggregate normal consumption is greatly increased. A few thousand gallons thus wasted by each consumer in a week or two amounts to an insignificant sum at the usual rates, whereas the heating appliances for rendering such draft unnecessary may cost him a large amount or may even be impracticable. This condition often exists in the great majority of the buildings of our smaller cities, and when the interest on the cost of providing the water for such waste is less than that of preventing it,

* *Transactions*, Am. Soc. C. E., vol. xix, p. 89.

the extra draft becomes economically expedient and justifiable. Mr. Kuichling. Proper limits are, however, here again necessary.

The various sources of loss and waste may be classified as follows:

1.—Loss or error in computing or measuring the original quantity;

2.—Losses in conveyance and storage;

3.—Losses in distributing the supply within the corporation limits;

4.—Losses through defective pipes, fittings and appliances in buildings;

5.—Unnecessary consumption in buildings and for public purposes.

Each of these classes admits of more or less subdivision, and for each component a reasonable numerical limit can be assigned. It may also be added that interest in the topic will be greatly stimulated by accounts of the methods used in arriving at the figures adopted as standards; and it is hoped that much in this direction will be accomplished in the discussion which is now opened.

Gardner S. Williams, M. Am. Soc. C. E.—Some diagrams are Mr. Williams presented herewith, which, it is hoped, may be found to be of interest in connection with this subject. They represent the results of some investigations which were carried on in Detroit, Mich., during the speaker's connection with those works, and show quite clearly some of the conditions that must be taken into account in settling upon the probable daily consumption of water to be provided for.

On Fig. 1 is shown the hourly consumption, as determined by plunger displacements, with an allowance of 2% for slip, on four days during 1895, which have been selected as being representative of the different conditions of service for that year. The speaker would not wish to be understood as endorsing the allowance of 2% for slip as a proper one, but as that was the allowance originally made for these engines, and as it has been adhered to in published reports, it is therefore accepted here. It will be noticed that the day begins at 2 A. M., that being about the time of minimum consumption.

February 9th, 1895, represents a typical day of extreme cold-weather consumption, and the excess of the maximum hourly consumption over the minimum is only about 18%, or the variation of consumption is about 11% above the mean and 6% below it. The total daily consumption is about 50% in excess of the average for the year.

June 18th, 1895, represents a typical day of extreme hot-weather consumption, which is the time of maximum hourly consumption and of its maximum variation, the maximum hourly consumption being 167% greater than the minimum, and 36% above the mean, while the minimum is 49% below it. The daily consumption is about 25% in excess of the average for the year.

August 1st, 1895, represents a day corresponding quite closely to

Mr. Williams. the mean day for the year. The mean daily consumption for 1895 was 40 269 731 galls., and that of the day shown was 40 577 100 galls. The maximum hourly consumption is seen to be about twice the minimum, and the variation from the mean is 49% above and 37% below. The consumption throughout the business hours of the day is seen to be quite uniform, a marked contrast to that of June 18th, in which there is a decided maximum in the afternoon, the consumption between 7 and 8 in the evening being greater than that of any hour in the forenoon.

November 10th, 1895, represents the day of minimum consumption, which was Sunday. The regular drop of the afternoon consumption is a characteristic of Sundays and holidays. Here the minimum is about 74% of the maximum, the variation from the mean being 20% above and 30% below. The total consumption on this day is about 66% of the mean for the year.

Fig. 2 shows quite clearly the effects of the daily variations of temperature and of precipitation upon the consumption of water. As at this time there was no restriction placed upon lawn sprinkling, the use of water for the purpose being without charge, it is probable that the results presented in this diagram are likely to be in excess of those in almost any other community. Meteorological conditions occurred at this time which were exceptionally favorable to a determination of the quantity of water used for sprinkling and cooling purposes. The week preceding Monday, June 3d, had been hot and dry, and each day had shown a marked increase of consumption over the corresponding day of the week before. On Monday the consumption reached 52 578 764 galls., which, when combined with the head pumped against, represented 55 313 916 157 foot-pounds of work at the engines. As the preceding day was Sunday, a day of low afternoon and evening consumption, the quantity of water pumped early Monday morning was less than would have been the case otherwise, as is shown by the record of Tuesday, in which the cross-hatched areas represent the hourly excesses of work over the corresponding hours of the day before, and it will be seen that, up to 8 A. M., Tuesday promised to be a day of greater consumption than Monday, but about this time a storm began brewing and rain fell from 9.45 A. M. to 8 P. M. in a gentle shower, the total precipitation being 0.17 in. This, and the accompanying fall of temperature, which is shown in the lower part of the diagram, caused the consumption of water to fall off rapidly, and by Wednesday it had fallen to almost exactly that of the mean day for the year. On this day's plotting the cross-hatched areas represent excess of work over corresponding hours on Monday. It seems fair to assume that the differences in consumption and work between Monday and Wednesday represent the amounts of each due to lawn sprinkling and the use of water for cooling purposes, when correc-

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HOURLY CONSUMPTION OF WATER AT DETROIT.

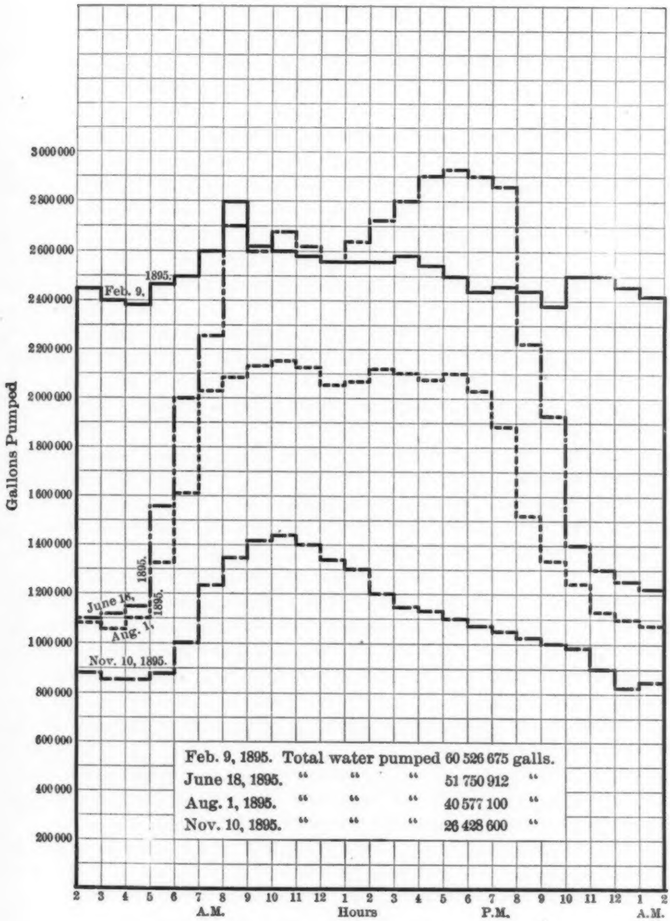


FIG. 1.

Mr. Williams. tion is made for the fire on Monday afternoon, represented by the double hatching between 5 and 8 P. M., when four steamers were called into service; and for the variations between Sunday and week-night consumption. This gives, for the work of the engines due to sprinkling and other hot-weather uses, 15 475 131 167 foot-pounds, or more than one-third of the average daily work for the year, and the consumption of water due to these causes was more than 12 000 000 galls., or nearly 25% of the average daily for the year. The shaded area on Monday represents this excess of work, and shows clearly the distribution of such usage throughout the twenty-four hours.

These charts show conclusively that in determining the quantity of water to be provided, temperature and precipitation are elements of prime importance. To summarize the results of the studies of these effects, which have extended over several years at Detroit, during all of which time hourly records of discharge have been kept, as well as of head pumped against and pressure upon the system at some twenty different locations, it may be said:

(*a*) For a range of temperature between the freezing point and about 50° Fahr. neither changes of temperature nor amount of rainfall has any appreciable effect upon the consumption of water, and, of course, precipitation has very little effect when the temperature is below freezing.

(*b*) That for temperatures above 50° Fahr., increase of temperature increases consumption, and a decrease of temperature or an increase of precipitation decreases consumption.

(*c*) That for temperatures below the freezing point a decrease of temperature increases consumption.

(*d*) That consumption lags behind temperature changes. For instance, after high temperature the consumption will remain high until the temperature has reached a few degrees below where it was when consumption began to increase, and after low temperature the consumption will remain high until a considerable time after the mercury has passed above the freezing point.

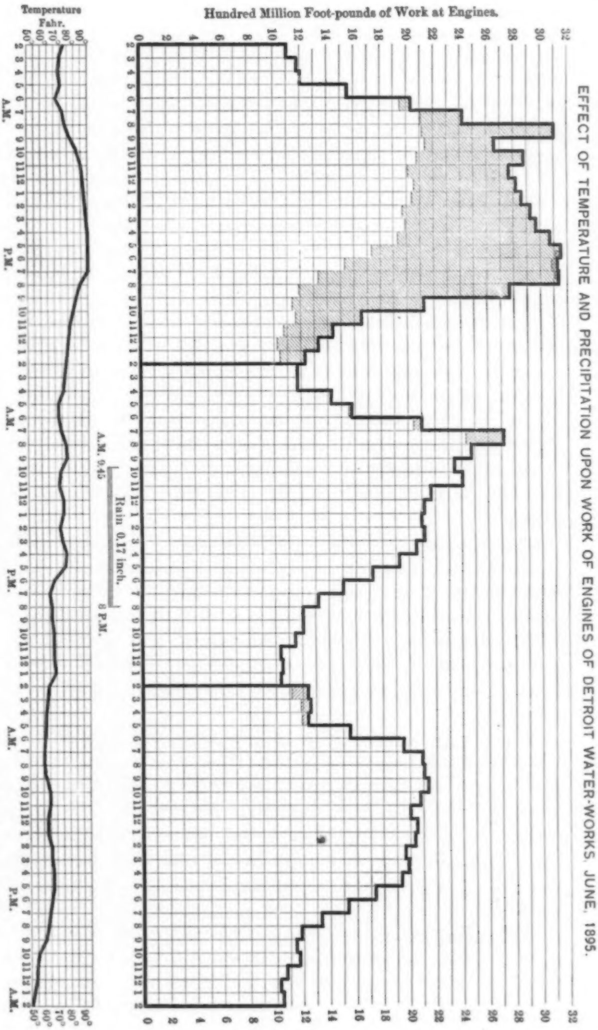
As these matters have been more extensively discussed in the speaker's reports,* and also in an article, "Notes on Water Consumption," in *The Technic*† for 1897, where other interesting data regarding consumption in Detroit are given, the several other interesting features of these diagrams will not be considered here.

Fig. 3 represents, by the areas enclosed between the base and the upper stepped line, the mean daily consumption per consumer of water in the City of Detroit for each year from 1871 to 1899, inclusive, the total quantity of water pumped being determined by plunger dis-

* Reports, Board of Water Commissioners, Detroit, Mich., for 1894, 1895, 1896 and 1897.

† Published by The Engineering Society of the University of Michigan, Ann Arbor, Mich.

Mr. Williams.



Monday, June 3d.
Total Work = 55 313 916 157 Foot-pounds.
Total Water Pumped = 52 578 764 Gallons.

Tuesday, June 4th.
Total Work = 40 913 893 058 Foot-pounds.
Total Water Pumped = 41 162 859 Gallons.

Wednesday, June 5th.
Total Work = 40 395 986 881 Foot-pounds.
Total Water Pumped = 40 380 270 Gallons.

Excess of Work June 3d over Work June 5th = 14 917 930 276 Foot-pounds.
" " Water " " " Water " " = 12 198 194 Gallons.

FIG. 2.

Mr. Williams. placement as already described, and the number of consumers being obtained by multiplying the number of families using water in the city by the factor 5.14, that being the mean value of the number of persons per family, deduced from the United States censuses for 1860, 1870, 1880 and 1890. It may be remarked that owing to the modern tendency to smaller families, which is clearly shown by the later censuses, and to the concentration of population at times of financial depression and its dispersion under opposite conditions, the use of a constant factor is not strictly accurate, but the general form of the consumption area would not be greatly changed were corrections made to account for these conditions. It may be further remarked that more than 99% of the entire population of Detroit is supplied with water from the municipal works, there being no other source available for domestic use.

The shaded areas along the upper bounding line represent the average daily quantity of water per consumer sold by meter. The upper broken line represents the mean temperature for June, July and August, or the hot months, and the lower similar line represents the mean temperature for the cold months, January, February, March and December; while the lower shaded area represents the mean total monthly precipitation for the months of May, June, July, August and September, wherein rainfall may affect consumption.

On this chart the effects of temperature and precipitation can be clearly traced, where, for example, it is seen that the very low winter temperature of 1875 was responsible for high consumption, while in 1881 this appears to have been due to high summer temperature and low precipitation. In 1882 high winter and low summer temperature combined to give a low consumption, while in 1893 and 1895, and again in 1899, the opposite conditions conspired to the opposite result.

This chart is further of interest in connection with the effect of metering upon the consumption of water in Detroit. Notwithstanding that oft-quoted statements and figures from the official reports of these works are widely in error, and have been allowed to go unchallenged for several years, the speaker would not care to raise those points at this time or in this place, were it not that such statements, made by an official of those works, are on record in the *Transactions* of this Society.*

The statement is frequently made in the official publications that the reduction of consumption from the maximum in 1888 to the minimum of 1892 was due to the saving of water caused by metering. From this chart it will be seen that the quantity of water paid for by meter in 1889 was only about twice that similarly paid for in 1888,

* *Transactions*, Am. Soc. C. E., Vol. xxvi, pp. 49-52.

Mr. Williams.

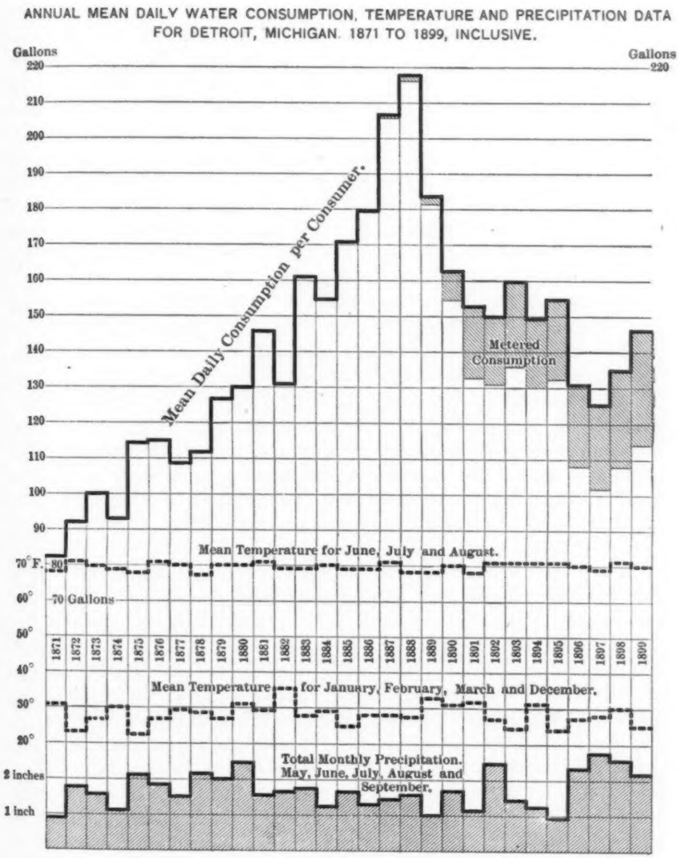


FIG. 3.

Mr. Williams. and yet the saving is nearly twice as great as during the following year, when four times as much water was sold by meter, and beyond 1890 it appears that the increase in metered water has very little bearing upon the variation of consumption. These facts are sufficient to arouse suspicions as to the remarkable efficacy claimed for the meters; and when it was found by a computation of the discharging capacity of the connections metered in 1889, that if they had all been running wide open twenty-four hours in the day in 1888 and until metered in 1889, and had been closed completely during the portion of 1889 after the meters were set, the amount they would have reduced the consumption would not begin to account for the saving claimed, it became evident that some other cause of reduced consumption was to be looked for, and upon investigation it was found that the bulk of the saving between 1888 and 1892 was due to the restriction of waste at the engines themselves, and had no connection with the meters further than that it was instituted at the same time and for the same purpose that the meters were introduced.

Previous to 1888 it was customary to open the waste-gate at the pumping engines and pump back into the river rather than lay off an engine at night when the consumption fell below a certain point. The engineer in charge of the station was very severe with his subordinates when an engine stopped, and beam engines, fly-wheel engines, are likely to stop if they run below a certain rate of speed; so when the engines were slowed down to nearly their minimum capacity the attendants opened the waste-gates, discharging back into the pump-well, to keep them pumping during the night, thus avoiding danger of trouble from having to get the chief up early in the morning to start the engines again.

It is interesting to note the decided jump in consumption from 1886 to 1887. By tracing this increase back it was found that the jump began at the time the reservoir was cut off from the system. Up to October, 1886, the Detroit system was a combination of reservoir and direct pressure, the water being pumped directly into the mains, but the reservoir being so connected that a surplus accumulated there, so that then it was not necessary to waste much water, because generally there was a chance to pump 8 or 9 ft. depth of water into the reservoir at the times when the consumption was low. But the reservoir was disconnected from the system in 1886 because it was felt that it did not afford opportunity for sufficiently high pressures, and an increased waste at the engines commenced immediately, the jump being noticeable the very first day after the reservoir was abandoned, and the waste continued to increase until, in 1888, it had become so great that the Board of Water Commissioners was appalled at the quantity of water which was being pumped, a large portion of which was never getting to the city at all. The Board feared that it would

have to reconstruct the entire system at that rate inside of five years; Mr. Williams. and the only alternative appeared to be to introduce meters, which it began to do at once.

There were some notable cases of reduction of consumption when those first meters were put in, but nothing that would account for anywhere near the drop which actually took place. Simultaneously with the introduction of the meters, the waste at the engines was curtailed, and as little water was wasted there as could be with the devices that existed for controlling the machinery, for there were times when it was necessary to waste some water. In 1893, when the speaker's connection with the works began, he had a record kept of the opening of the waste-gates, the time during which they were open, the number of turns, etc., and began estimating the quantity of water wasted in that way; and although at that time it was supposed that there was no waste, or at least that no more water was wasted than was absolutely necessary, it was found that the waste gates sometimes discharged anywhere from 500 000 to 2 000 000 galls. a day. When this waste was so great under those conditions, it can readily be imagined that considerably more had been wasted when there was no attempt to restrict the quantity thus lost. Comparisons between Sunday and weekday consumptions in 1888 showed that from 7 000 000 to 10 000 000 galls. had been wasted daily on some occasions. In 1894 the engines were remodeled, and by 1895 they were so arranged that it was unnecessary to waste. Since early in 1895 there has been no loss of water pumped at the engines in the Detroit works.

In establishing the necessary quantity of water to be allowed, it is the speaker's opinion that the range of temperature must be taken into consideration, and also the latitude of the locality in question; whether, for instance, it is in New York or in Georgia. The freedom with which the use of water for cooling purposes, for sprinkling purposes, etc., is permitted, must also be considered, as well as the character of the population. It seems impossible to lay down any hard-and-fast rule on this subject, because so many varying conditions are encountered.

There are manufacturing communities in this country where the consumption of water is reported to be only about 30 galls. *per capita.* In the City of Detroit the manufacturing and business consumption alone, all of which was metered, has amounted to more than 20 galls. per consumer, in fact to about 25 galls.; and when we reflect that in that city a large proportion of the factories draw their supplies directly from the river, and that few authorities have had the temerity to recommend 5 galls. as a proper domestic allowance *per capita,* one is led to question whether the 30 galls. *per capita* claimed in some places is not 30 galls. per inhabitant, and very possibly 60 galls. per consumer.

Mr. Williams. In June, 1896, the record of consumption of 819 private families in Detroit supplied by meter was 45 galls. per person daily, and the average daily consumption for June was less than 1% from the average for the year. These 819 families were taken at random, but probably represented mainly the middle class, and did not include more than half a dozen first-class residences. Although the speaker at one time* estimated 23 galls. per person as a proper domestic allowance for Detroit, in the light of later developments he would place the limit at nearly double that quantity.

Mr. Trautwine. JOHN C. TRAUTWINE, Jr., Assoc. Am. Soc. C. E.—Fortunately, it is no longer necessary to argue with engineers in favor of water-waste restriction, and there is practical unanimity as to the means by which such restriction may and should be accomplished; but, unfortunately, the water-works of too many American cities are managed, not by engineers, but by bodies of laymen, destitute of technical knowledge, and apt to follow the uneducated judgment of the people at large, when they are not following something less commendable. It is, therefore, in most cases, necessary for the engineer to obtain the consent of the people to be benefited in the manner he proposes, and it would seem that the only question left to discuss is, how best to obtain that consent.

For those of us who think, it is difficult to grasp the inefficacy of argument, based upon facts, in educating the public. For four years, as Chief of the Bureau of Water in Philadelphia, the speaker was instant, in season (and possibly now and then out of season) in holding up before the people the enormity and absurdity of the city's waste of water, and the deplorable consequences of that waste. He showed them that probably three-fourths of all the water pumped was being wasted, and that by a very small minority of the people, who were thus victimizing the great and stupid majority. He showed them how this waste deprived them of an ample supply and threatened the imposition of enormous additional financial burdens for no useful purpose. The people said, "We are opposed to meters." Even the grave and reverend *Public Ledger* echoed (and it still keeps re-echoing) the antediluvian cry, "Let water be as free as air," and those who condescended to use their gray matter at all in connection with the subject, asked, "How can we waste what we do not get?"

The speaker, therefore, presents his experience as a rather melancholy instance of the inefficacy of what may be called the direct or argumentative method of public education, and he would be glad to learn of more effective methods.

The speaker is glad to learn, from Professor Humphreys, that an object lesson, presented before a college of apostles, may be of use after all, and that the primer which the speaker produced before the

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* *Michigan Engineer's Annual*, 1895.

American Water-Works Association, at Richmond, last year, has found its way into the hands of an abler educator, and is bearing fruit. Mr. Trautwine.

Some caution is proper in applying the data of Mr. Hering's table to the question of the advisability of installing meters in a given case. For instance, the Philadelphia works, from 1895 to 1899, were actually driven to their utmost, every pump working night and day, in the hopeless task of filling a sieve, while the Bureau of Water was besieged with complaints, personal, telephonic and by correspondence, of shocking cases of short supply. A majority of the representatives of the people, in Select and Common Councils assembled, being hostile to the existing administration, would permit no waste restriction and would grant no dollar for extensions and improvements, though they were not backward in asking for estimates of cost of filtration and extension. In response to one of these requests, the writer submitted a report, showing that, if \$1 000 000 were expended upon meters, the cost of installation for filtration and other improvements would be about \$3 600 000; whereas, if the waste continued unchecked, about \$12 500 000 would be required. In cases like this it might be found that the introduction of meters was most desirable, even though, upon the basis of Mr. Hering's table, it might uppear uneconomical.

From the experience of Moscow it appears that an effective means of waste restriction would be the abolition of existing sewerage systems. In Moscow, a few years ago, without a system of sewerage, it was more difficult to get the water away from a house than to bring it there, and the consumption amounted to only 6 galls. per head per day.

Rudolph Hering, M. Am. Soc. C. E.—Mr. Trautwine's remarks express substantially the speaker's views, with, perhaps, one exception. Mr. Hering.

While all seem to be of one opinion, and should be so, regarding the advisability of preventing, so far as possible, all needless waste of the public water supply, it is necessary, in endeavoring to secure to this end the hearty co-operation of the public, to present not only a thoroughly just and practicable method, but one which will not in disguise substitute one injustice for another. Needless waste by some users, strictly speaking, correspondingly reduces the supply and its pressure for other users, or, if the supply be correspondingly augmented, it thereby increases the general expense. Herein lies, clearly, an injustice to the careful user. On the other hand, whenever it occurs in an individual case that the expense of restricting the waste is greater than the cost of furnishing the water which is saved by the restriction, then, paying by meter measurement would be manifestly as absurd as paying more than one dollar to get one dollar's worth of gold out of a mine. In this case the "careful user," who is economical and in the majority, would be forced to pay a part of the expense of a general introduction of meters, neces-

Mr. Hering. sitated by the comparatively few extravagant or wasteful users, and once more we do an injustice to the former, and establish a penalty for thrift.

A year ago, when connected with an investigation of the water supply of New York, this question was prominently brought forward. The cost of the water delivered at the city line, at an elevation of 300 ft., more or less, varied, in the several projects investigated, from $8 to $32.25 per million gallons, including interest, depreciation and maintenance.* Investigations made in Philadelphia two years ago indicated that the cost of delivering water into the city reservoirs varied in the several projects from $15.10 to $19.70 per million gallons, including interest, depreciation, pumping and maintenance.† At the pumping stations in some of our large Lake cities, the cost of water delivered under pressure per million gallons, including interest, depreciation on pumping plant and intake tunnels, pumping and maintenance is as follows: Chicago, about $11.50; Milwaukee, including the high-service lift, $12.62, and Erie, Pa., about $23. The additional cost for distribution is estimated as follows: Chicago, about $8, and Erie, including reservoir, about $16.

With these facts before him, the speaker prepared Table No. 1 in order to indicate in figures what bearing the question of the cost of water would have upon the meter question. It should be added that, of course, the complete cost of water would include not only the cost delivered into the reservoirs, but also into the buildings, and the cost of fixtures, etc. In fact, strictly speaking, it might be made to include also the resulting sewerage works, which are but a continuation and made necessary by the existence of the water supply system. For the purpose then had in view, the cost of the delivery into the existing distribution system, excluding the cost of the latter, was deemed proper. To include the cost of the distribution system would mean to add the interest on the investment, the depreciation of the pipes and appurtenances and the cost of general maintenance; then reduce the same to 1 000 000 galls. of water consumed, and find the corresponding value representing the cost of the water in Table No. 1.

The permanent cost of introducing a meter service into an ordinary dwelling-house may vary from $2 to $3 per annum. This includes the cost of installing the meter, keeping it in repair and replacing it with a new one every ten years; and includes the cost of reading it quarterly and of keeping the accounts. With a perpetual running cost of $2 or $3 per annum for metering, we should clearly expect to save thereby, respectively, at least $2 or $3 worth of water. The table supposes that

* "The Water Supply of the City of New York," by the Merchants' Association of New York, August, 1900.

† "Report on the Extension and Improvement of the Water Supply of the City of Philadelphia," by Rudolph Hering, Joseph M. Wilson, Samuel M. Gray, Commissioners; September, 1899.

only the less amount is saved, and indicates the number of persons per meter more than which makes a meter economical, under three conditions of waste, namely, of saving 25, 50 or 75 galls. per day per person, and assuming the cost of the water to be $10, $25, $50, $75 or $100 per million gallons. If the cost of metering a dwelling-house should be $3 instead of $2, then 50% would have to be added to the number of occupants given in the table. Mr. Hering.

TABLE No. 1.

Number of Gallons which a Meter is Expected to Save per Day.		Cost of Water to City, per Million Gallons, Delivered into the Distribution System.*				
		$10.	$25.	$50.	$75.	$100.
Per head.	Per family of six persons.	Number of dwelling-house occupants, more than which makes the use of a single meter ($\frac{1}{2}$-in. or $\frac{5}{8}$-in.) economical, when the perpetual cost of a meter service is not over $2 per annum.				
(1)	(2)	(3)	(4)	(5)	(6)	(7)
25............	150	21.9	8.7	4.4	2.9	2.2
50............	300	10.0	4.4	2.2	1.5	1.0
75............	450	7.3	2.9	1.5	1.0	0.7

* Columns 3 and 4 might not include the cost of the distribution system.

The table is constructed from the following formula:

Let a designate the cost of the service of meter, in dollars per annum;

Let b designate the number of gallons saved by the meter service per consumer per day;

Let c designate the cost of water, in dollars per million gallons delivered by the city;

Let n designate the number of consumers using one meter.

Then let the cost of the meter service equal the cost of the number of gallons saved, or,

$$a = 365\ b\ n\ \frac{c}{1\ 000\ 000}$$

or, reduced to n,

$$n = \frac{1\ 000\ 000\ a}{365\ b\ c}.$$

Whatever quantity of water disappears by leakage, unpreventable waste on its way from the reservoir to the buildings, public hydrants, or fountains, and the quantity under-registered by the meters must, of course, be accounted for, and should be proportionately charged against private and public service, thus raising the cost per million gallons usefully consumed. Thus, unpreventable loss will vary greatly, and chiefly with the care that has been taken in the construction and maintenance of the works. In well-managed works it need not be over 15%; but even if it were 25% of all the water delivered, it would deduct but one-quarter from the number of occupants given in the table.

The table shows that, with any reasonable allowances, and in a city where water is cheap, it is not economical, as a general rule, to place meters in houses for small families, because it may then cost less to let a certain amount of water go to waste than to provide means for check-

Mr. Hering. ing it. This argument has been often made before; practical business men see the strength of it, and engineers certainly do not wish to ignore it. Unfortunately, however, it is sometimes used to oppose the introduction of meters into any house whatsoever, a conclusion altogether without reason or justice.

To deal successfully with this matter, we should, therefore, discriminate carefully, and recommend meters only for those buildings and users where the probable saving will at least pay for the meter service. And, in summing up the whole question, it appears to the speaker that the best way at present to handle the introduction of meters is:

First, to have the city or water company own the meters in all cases.

Second, to give every user the opportunity to pay for his consumption of water by meter, if he wishes to do so, and can, thereby, save himself money beyond a fixed minimum charge.

Third, to give the authorities the right to exact payment by meter measurement from any user, not only in all cases where the water is used for manufacturing or business purposes, but also in any private house when these authorities have reason to believe that the domestic consumption is greater than the quantity covered by certain fixed rates. Where water is expensive, this would mean a meter service for perhaps every house; where water is cheap, all the smaller dwelling-houses would, as a rule, require none.

It is questionable whether the greatest waste of water in a city, as shown by reported figures, is attributable to the carelessness of private consumers. J. James R. Croes, President, Am. Soc. C. E., in his examination of the New York water supply, estimates that, of the total waste, only one-fifth is inside of the houses, and four-fifths on the streets and in old taps or unused service pipes. In Philadelphia it seems probable that a similar condition exists. It appears, therefore, that in addition to the reduction of undue waste in houses, the cities should similarly examine into the economical question of reducing the waste from underground leakage.

As suggested, a district meter system can be introduced, to localize and measure leakage; then it can be ascertained, somewhat as above, whether the cost of repairing a particular leak is or is not justified by the value of the water to be saved, or by the amount of damage being done by the leak.

Another point seems to need emphasis, in view of the conclusions which have been repeatedly drawn. We frequently hear of the evidence from Fall River, Woonsocket, etc., quoted against that from New York, Philadelphia, Washington, Buffalo, etc., regarding the waste of water. The former class consists generally either of small cities, of those "having a preponderance of the operative class, whose average wealth and opportunities for luxuries" in the use of water are

small, or of those cities which are fortunate in possessing a continuance of good and vigilant officials, keeping the waste in check. The other class consists generally of cities of large population, of wealth and luxury, in which the officials have less opportunity closely to look after and control individual consumers, and in which there is sometimes a disposition to resist anything that might, though mistakably so, appear to curtail a citizen in the liberal use of all the water he needs. Mr. Hering.

Those of the latter class unquestionably and properly require a larger *per capita* supply than those of the former.

Among individual consumers, also, we almost invariably find in the houses of the wealthier class a very much greater *per capita* use than in the houses of the poorer class. It is likewise true that, along with an increase in the standard of living, from decade to decade, the legitimate *per capita* water consumption has also increased and may increase still more.

For one who has always been emphatically opposed to the waste of water and who has favored every rational means of preventing the same, it may seem contradictory to take issue with some of those engineers who desire the same end. The present question, however, is chiefly one of means, of practicable means to secure this much-desired end, and on this question of means there may be a reasonable difference of opinion.

Referring to the writer's opinion, that meters should generally be omitted in houses for small families in those cities where water is very cheap and whenever in consequence thereof a meter service would cost more than the water saved, Mr. Crowell, in his discussion, disagrees, but does not adduce any fact or clear reason why he cannot agree to this proposition. To enlarge somewhat upon this matter, the writer does not believe, nor did he ever believe, that meters should in any case be prohibited. He is desirous of seeing the waste of water, and, therefore, of money, reduced as far as it is economical. To this end he believes that the city should have the privilege to meter every house, but should place a meter only wherever it pays the city to do so; and, further, the user should have the same privilege, and should be entitled to demand the placing of a meter whenever it pays him to do so. In both cases, public and private, this is virtually a recommendation to introduce, not to prohibit, meters; and, as the writer further believes, this recommendation in both cases is based on a fundamental principle of equity and true economy, and therefore practicable. So long as we insist on metering every house, even when it can be shown to entail a loss of money, we are likely to defeat our very object, and cause the people to postpone, if not permanently reject, the more general introduction of meters.

When there is so much difficulty in convincing certain classes of

Mr. Hering water users that metering their supply would save them money, instead of the contrary, and in convincing some city governments that a more general introduction of meters would reduce operating expenses and postpone the day for enlarging their works, an endeavor should be made to throw no obstacles in the way of the best means of accomplishing this much-desired result. We should, on the contrary, try to make the way easy and smooth, and should use a rational method which, from its fairness, will appeal directly to those who must pay the bill, and which will gradually but surely obtain the wished-for result.

Mr. Crowell refers to his article on "The Use and Waste of Water in New York City." He expresses therein his opinion that in Manhattan and the Bronx a total supply of 107 000 000, or 55 galls. per head per day of the resident population, would be a sufficient allowance, instead of the present consumption of these districts, which is over 227 000 000 or 117 galls. per head per day of resident population; the difference being a theoretically preventable waste of 120 000 000 galls. per day. He estimates "the possible saving," that is, "the extent to which the prevention (of waste) can be carried," "as a very considerable part of the theoretical amount."

John R. Freeman, M. Am. Soc. C. E., states* his conclusions on the practical chances of reducing the present *per capita* supply in the City of New York, so as to postpone the inauguration of a new supply, as follows:

"It is dangerous to public interests to be too hopeful about preventing waste when estimating the date when the new supply must be available, or in estimating its necessary magnitude, for with these hopes unfulfilled and the reservoirs empty, the disaster would then be beyond remedy."

The Engineering Committee of the Merchants' Association, referred to by Mr. Crowell, in view of all the evidence before it, unanimously shared Mr. Freeman's views, and advised taking immediate steps for an increased supply as the most proper practical solution of the question, not believing it to be safe to rely on a material reduction of waste.

In view of the enormous floating population of New York, the foregoing figures given by Mr. Crowell are somewhat misleading, because, if the actual number of water consumers, including the large number of transients constantly in New York, is considered, the resident *per capita* rate, and therefore the apparent waste, would be correspondingly reduced.

In his discussion, Mr. Crowell takes exception to the statement "so often heard," that the *per capita* water consumption increases generally as wealth and luxury increase. He does not substantiate his

* "Report on New York's Water Supply, Made to Bird S. Coler, Comptroller," by John R. Freeman, March, 1900.

exception by statistics. The writer believes that this would indeed be difficult, unless there was a metering for substantially every house and a comparison in each one with the wealth of the residents, as measured perhaps by the property tax or the rent. So far as this has been done, in the writer's experience, the result has roughly indicated such a relation between the average consumption per user and the average rental of the dwelling, provided extreme cases and trade water are excluded. This result has been noticed in Europe as well as here, but here, also, no statistics seem to be available. Mr. Hering.

If the figure representing the entire delivery of water is divided by the figure representing the entire resident population, thus getting the so-called *per capita* supply, making no deduction for that part of the population which is not supplied, nor considering the transient population which is supplied, nor taking special account of the quantity of water used for manufacturing purposes, the above relation between wealth and consumption may naturally become much distorted.

It may not be amiss to emphasize again, that in large cities meters may not be the chief remedy against waste. There is in some cities a very large loss of water outside of the buildings, as pointed out frequently. Old service pipes and mains furnish a large proportion of the waste, and the resulting leakage needs correction fully as much as the waste in dwellings.

The under-registration of meters is another question that should have a careful consideration. When tested, their slip is known. After running for some time, the slip is known to increase, and a case, once before the writer, revealed, under a light flow, a slip of about 50 per cent.

From what is said above, the wastage inferred from meter records, therefore, is not always actual, except in rare cases. It may sometimes be as delusive as that recorded for pumpage when the actual slip of the pumps is not accurately known. Or, it may be deduced from a delusive figure as to the actual water consumers. Or, the loss of water by leakage in streets and on public grounds may in part tacitly be assumed as being due to waste by private consumers.

Desmond FitzGerald, Past-President, Am. Soc. C. E.—The speaker believes in taking every reasonable step to stop needless and willful waste of water. Here is a shining example of the beneficent results arising from the general introduction of meters. Recently, the speaker was consulted by a city in regard to an additional supply of water, and in the course of his investigations found the following remarkable conditions: Population, 40 063; consumption *per capita*, 29.3 galls.; domestic use, metered, 10.9 galls., and unmetered, 2.5 galls.; manufacturing, 4 galls.; street sprinkling, 2.5 galls.; fountains, 1.3 galls.; unaccounted, 8.1 galls. The latter includes water used for fires, flushing sewers and Mr. FitzGerald.

Mr Fitzgerald. water mains and puddling trenches. One of the interesting facts in connection with this city is that there has been no increase *per capita* in the consumption during the past six years. The total number of meters in use is 4 300; total number of services, 5 275, and about one-third of the whole supply is used for manufacturing purposes. The water for street sprinkling and for fountains is measured.

In order to check the small waste unaccounted for, the speaker made measurements of the fall of the water in the stand-pipe between the hours of 1.00 and 5.00 A. M., and found it to check almost exactly with the foregoing amount of 8.1 galls. *per capita* unaccounted for. Probably this loss is due to leakage in the pipes or unmetered connections, as the legitimate use of water in the early morning must be very small.

It is evident, on investigation, that in this case everyone uses all the water he desires, and, as there is an excellent sewerage system, the plumbing is on a liberal scale for a city of this size. The contrast between the foregoing excellent administration of a public water supply and that prevailing where no attention is paid to the restriction of waste is refreshing.

Mr. Owen. JAMES OWEN, M. Am. Soc. C. E.—The pressure under which water is delivered is a potent factor in the checking of waste. In the average small town which is compelled to supply water for fire purposes without the aid of a steam fire-engine, it will be found that the daily consumption of water is at least 20 to 30% more than in those cases where water is delivered under the ordinary house pressure, and without the requirements of fire service. This would show that the loss, as Mr. Herschel says, is behind the meter, to a large extent. Incidentally, also, there is a great loss through the fixtures, due to a higher pressure.

Another point, which may savor of heresy, is that the engineer in charge of a water plant should control the supply, to a certain extent, if he can. The speaker does not think that the public is educated up to the idea that they should not have all the water they can get, but they should be educated up to the idea that they can use only what is given them. That has been a matter of practice, secretly, in a great many cities where the service supply has been very short and where the gates have had to be closed in order to curtail the supply. In one case, during a shortage of water, the speaker made a practice of shutting off nearly all the water. A by-pass was put in by which the ordinary 12-in. main was reduced to a 2½-in. feeder. This practice was carried on for about two months before anyone found it out. The result was that the night consumption during hot weather was reduced to a minimum, and the period of dry weather was safely passed. In regard to such cases the speaker suggests that it may be possible for the engineer in charge of a water supply to arrogate to himself, perhaps,

the control of this service according to the conditions. It is too often Mr. Owen. the case that the engineer tries to give the people all there is.

In another instance a serious epidemic, resulting in many cases of sickness, was caused by the effort of the engineer to give an alternate supply, of water which was not proper to be used, in order to keep up the service and the pressure. If he had used what he had during the day and had simply reduced the pressure at night he would have had no trouble.

D. C. Humphreys, M. Am. Soc. C. E.—The speaker has made very Mr. Humphreys. effective use of the arguments given in Mr. Trautwine's paper, before the American Water-Works Association at Richmond, Va., in educating his fellow-citizens and the town council in the town in which he lives. In that town, some twelve years ago, the speaker put in an extension of the water-works, and since then he has been striving to obtain the introduction of meters in order to check the waste, but has found it to be a long and serious task.

The situation is as follows: The town has a population of 3 000 to 4 000 and the supply is obtained from springs and brought by gravity to a reservoir having a capacity of about 20 000 000 galls. The pressure from the reservoir is sufficient for fire purposes without the use of engines The town has taken a great interest in its fire company—the champion fire company of the State—and the result of this, and the excellent water supply, is that the fire insurance companies have reduced the cost of insurance to the minimum rates, which is appreciated greatly by the business men.

When the reservoir was built a waste gate was provided, and, as the supply was larger than the demand, a great deal of water was allowed to run to waste. Knowing this, the people naturally became extravagant. Everyone used as much as he wanted, and said, "What is the use of saving it?" In the fall of the year, however, the springs, generally, run low, and there is no longer a surplus; all that comes to the reservoir is needed. Last fall all the water was drawn out, and then Mr. Owen's scheme of shutting off the supply was adopted, which was not very pleasant for those having lawns or for those who had been accustomed to having the streets sprinkled.

A severe lesson is probably needed in order to emphasize the necessity of curtailing waste. If a fire occurred at a time when the water supply was low, the fire company would be unable to do anything and the insurance companies might put up the rates and say, "You have not the fire protection we assumed you had when we gave you low rates." That would probably make an effective impression.

The question of meters, as a help in eliminating water waste, is no longer in dispute by engineers. The main point is to get the public to appreciate their advantages. Those who put in meters in this town wanted to put in the cheapest they could get, as they had to purchase

Mr. Humphreys. them. The town should furnish the meter, keep it in order, and charge an annual rental. A meter should be put in wherever there is a water-closet, but in the poorer houses, having only one spigot, inspection alone should be sufficient to check waste.

Mr. Maignen. J. P. A. Maignen, Assoc. Am. Soc. C. E.—There is a point which the speaker tried to raise two years ago at the Cape May Convention, which has not yet been alluded to in this discussion, and which he would like to bring forward for consideration. A double supply exists in Paris. One is plain, unfiltered river water under a comparatively low pressure; the other is spring water and filtered water which is pumped to higher reservoirs, and which is, therefore, under greater pressure.

The plain river water is sold at 12 cents per thousand gallons, and the spring and filtered water at 24 cents. If, on account of its pressure, anyone wants to use this latter water for elevators, carriage washing, industrial or other base purpose, the charge is 48 cents per thousand gallons. This is practically a fine to prevent the use of spring water for anything but dietary or other noble uses.

Streets are washed with the plain river water from hydrants with a hose that delivers enough water to wash all the dirt into the surface sewers. It is not a mere sprinkling, which leaves the mud on the streets, it is a thorough wash-out. It is evident that for such a purpose it is not necessary to have sterilized water or any great pressure.

It has been stated that in some little towns, in warm weather, the springs do not give enough water. Every now and then we hear that New York and other great cities are threatened with water famine. This would not occur if the best water were confined to nobler uses; common water being used for street washing, lawn sprinkling, fire, industrial and other indifferent uses; the better water, pumped under a higher pressure, being reserved for house use. The pipes for the purpose would probably never require duplicating or replacing by larger ones, as the population tends, not to increase on a given area, but to spread itself on larger areas; the population, particularly with increased conveying facilities, spreading itself farther and farther into the suburbs.

On the contrary, for industrial and municipal service, the needs may outgrow the capacity of the original pipes. In that case, larger or duplicate pipes may be installed to supply the increased demand. Such water can be given away, practically as the Philadelphians want it, free like air.

In some towns of France, along the coast, where pure water is scarce, sea-water is used for washing the streets, fire extinguishing, etc. The same has been done in several American towns.

Where the plain water is very roily, it might be subjected to a rough kind of filtration at a high rate, which would not be expensive.

It certainly seems to be a mistake to use sterilized water for all purposes, particularly with such enormous consumption and waste as is current in this country. Mr. Maignen.

J. N. Chester, M. Am. Soc. C. E.—Every water-works should have an income sufficient to pay its operating expenses, the interest on its investment and an additional amount sufficient to meet the cost of administration, whether that administration is by the officers of a private corporation or by the mayor and council of a city. The rates of any water company, whether flat or by meter, should be regulated accordingly; and, while the speaker heartily agrees with all that Mr. Hering and Mr. Herschel have said, he thinks that they are at variance in taking the revenue, one for the cost of supplying water and the other the total cost of operating the plant. Others, also, look purely upon the cost of pumping water, and not on other operating expenses and the interest on the investment. The speaker does not believe, however, in riding the horse of economy to death, which may be done by too rigid metering. A few years ago a striking example of this might have been seen in two suburbs of New York City, along the Sound. In one every tap was metered, and in the other very few were metered. In the fully metered town there were a few very wealthy people, and quite a number in moderate circumstances, but in that town there were very few well-kept lawns except those of the wealthy people; the poorer class and those in ordinary circumstances feeling that to water their lawns and keep them looking well was a burden. In the town where water was sold at the flat rate, almost everybody sprinkled their lawns. If a meter is put on, of course the waste is curtailed, and, on the other hand, in cases where the charges are materially changed by metering, the use of water for certain purposes is sometimes curtailed. At the ordinary charge of $6 per year for sprinkling a lawn, if the lawn be of any size, and the street in front be kept well watered, it will be found that at meter rates considerably more than $6 worth of water will be used in a year. On the other hand, if a water-closet is metered and is kept from leaking, it will be found that it uses scarcely more than $2 worth, though, with the exception of the lawn sprinkler, the water-closet is believed to be the source of greatest waste. A striking example of that occurred in Shreveport, La., not long ago, where a negro cabin, in which the only fixture was a water-closet, was metered. In this cabin one dollar's worth of water a day, at 30 cents per thousand gallons, was being used. That case is not exceptional. Mr. Chester.

The speaker thinks that the question of metering is largely one of locality. In some of the western cities if meters were adopted generally the lawns would be almost ruined. In places where nothing but alfalfa will grow, and that only by irrigation, and where the inhabitants are poor, it would be ruinous to put in meters.

Mr. Chester. It has been shown that to a certain extent metering will curtail the waste, and beyond that there is very little saving in consumption. That is the case in most places, and it is found that metering factories, saloons, hotels, livery stables and such places will stop the greater part of the waste, and that in most of our northern cities the consumption will not be excessive, but can be kept below 100 galls. per head, which is looked upon as an economical consumption.

Tables made up miscellaneously are misleading. Take, for instance, the case of Birmingham, Ala., where the supply to three industries is more than the consumption of that city would be at 100 galls. per head. The consumption in such a place cannot be compared with that of other places, and, while all the industrial establishments, saloons, livery stables, etc., are metered, the consumption is higher than that of any city supplied by the speaker's company.

There is a difference in the consumption in northern and southern cities. The colored citizen is not an extensive user of water, but he is an extensive waster. He seldom sprinkles his lawn, and does not care how dusty it is in front of his cabin. He is not noted for cleanliness, and never has a bath tub. Ordinarily, he only wants water in his house when the sanitary regulations of the city require him to put it in. The case of Shreveport, La., might be cited again as an example. In that city an ordinance compels every citizen within 320 ft. of a sewer and water main to put in a connection. Of the population of that city, 60% are colored. There is scarcely one of the colored population who utilizes the water or puts in a fixture other than the spigot which he is entitled to if he puts in a water-closet and a connection thereto; and yet that town shows a greater waste per head than most cities supplied by the speaker's company. That waste is determined by the minimum pumpage at night. The speaker has always said, and especially while he was the representative of a pump company, that few engineers appreciate the variation in consumption between the hours of 4 A. M. and 4 P. M., and between the ordinary spring and fall months, and the extreme cold weather; that is, where the temperature, as shown by Mr. Williams' diagrams, ranges between freezing and 50° Fahr., and where the precipitation is about uniform. On assuming charge of the Shreveport plant, the enormous waste was first brought to the speaker's attention by the fact that the pumpage at night was equal to that in the daytime, a condition which existed in no other plant in which the supply was direct, or through a stand-pipe, which is practically direct pressure. That brought out very clearly the fact that a great deal of water was being wasted, and an inspection showed that it occurred mostly among the poor or colored families, and came largely from the water-closets. The proposal to put meters upon those places was met with tremendous resistance by the political element, or the city government, which looked to those col-

ored people for votes just as much as it looked to the white element. Mr. Chester.
One councilman, with three in his family, and with a house and lawn of a size which gave him a rating of $80 per year, refused to vote for an ordinance allowing meters to be put in miscellaneously to curtail waste, saying that it would work hardship on the poorer people, and, while he felt that it might reduce his water rent from $80 to less than $15, he must decline to vote for the ordinance on account of the poorer people.

Oberlin Smith, M. Am. Soc. C. E.—One point does not seem to Mr. Smith.
have been brought out very strongly, and that is, whether it would be possible, and if so, how far possible, to regulate publicly the quality of plumbing fixtures. It is admitted that many of them are bad, but it is not realized how bad they generally are, and it is a question whether, by proper ordinances, and perhaps by having a commission in charge of the inspection and licensing of such apparatus, its quality might not be improved, and only good, durable, permanent apparatus be allowed. This is, at any rate, a direction in which this Society and the Water-Works Associations might move, to some extent. Mr. Herschel has spoken very disparagingly of paternalism, but the speaker believes in it in some cases—where it does good and where money is to be made by it. If a man is a good father and has a bad boy he gives him a spanking, and there paternalism is a very good thing.

Public regulation of the public is needed to a greater extent than obtains in this country especially. There is not enough of it in regard to many things of a public nature; and allowing anybody to put in the worst and most unserviceable plumbing fixtures, which do not get any regulation afterward, is a bad thing, and there should be some way of getting an improved practice, gradually, at least, if it cannot be done any faster. In the wash-basin at the hotel this morning, the speaker found a stream the size of a lead pencil running, and it had been running ever since yesterday morning, and the morning before. On attempting to shut it off it was found that the tap would not close. This is happening all around us; streams of water are running uselessly from all kinds of fixtures, and no one seems to have any very particular charge of it. Of course, the putting in of meters will improve the behavior of consumers in this respect. In general, there is no doubt that meters are a good thing, although there are cases where, as Mr. Hering suggests, they will not pay. The water companies, or the municipalities, should manage and keep in good order the whole plant as a plant, as has been mentioned, including the meters as a part of the plant. But we should deal properly with the consumer and sell him things at proper prices.

One of the points which should be emphasized particularly, is

Mr. Smith. the great importance of checking underground waste until the ideal system of the future comes—that of running all pipes in galleries where they will be accessible. The chief remedy that has here been suggested is the more frequent use of large meters in the mains, and the dividing of them into separate sections, so as to trace up these serious underground escapes.

Mr. Harlow. J. H. HARLOW, M. Am. Soc. C. E.—There are one or two facts which should not be forgotten. One is, that water is to be provided at the lowest rate and sold at some price which will justify the sale. There is no free water. The speaker has never seen it, and he has been in the business for thirty years.

On the question of the introduction of meters, a company with which the speaker is connected recently engaged to supply two small towns in which, in proportion to the population, or to the takers, an enormous amount of water was used. The consumption ran from 500 000 to 600 000 galls. per day, and the rates from $12 to $15 per year for a house of the ordinary kind, with ordinary fixtures and conveniences.

The company discussed the manner in which meters could be introduced without antagonizing the consumers, and made a schedule which brought the possible rate down to about $6 per year, leaving the taking of a meter optional with the consumer. Each consumer was to pay for at least 1 000 cu. ft. of water per quarter, and the company was to furnish the meter at a certain rental, or the consumer might furnish and own the meter.

The result has been that within a year the consumption has been reduced to less than 200 000 galls. per day, and the profit to the company is as great as it was before, while the expenses are much less. It is doubtful whether the consumers in these towns could be induced to go back to the old way.

Mr. Herschel. CLEMENS HERSCHEL, M. Am. Soc. C. E.—This is a subject with which the speaker has grappled in a practical sort of way for some years, not exactly, perhaps, as an engineer, but as a wholesaler of water. There are certain impressions, and a certain amount of ignorance in the public mind, which a society like this should endeavor to remove. There is not so much necessity for the education of the members themselves, for they all are pretty well posted. It was largely for this reason that, finding the American Water-Works Association was going to meet in New York this year, and having been a member of that Association for ten years, without ever having seen them, the speaker prepared a paper on this subject which was read before that Association lately in New York City, the members of that Association being very near to the public on this general subject.

The speaker's idea of consumption is that it is composed of waste and use; his idea of waste is, everything that is up stream from the

meter; his idea of use is, everything that the consumer chooses to pay for. The speaker does not believe in a paternal form of government; he believes that the average shrewd manufacturer would resent governmental interference with his business, and would consider that he did not need a wet-nurse to tell him how to get water for the least money. It is not practicable to endeavor to teach manufacturers, unless they want to be taught, and whenever they do want to be taught they have the means at hand by consulting the profession. There is so much of salient evil in this whole matter that the minutiæ of the business may well be left for future treatment. Such is the vast amount of water wasted up stream from the meter. The regular idea, the standard notion, prevailing, not only in the public mind, but in the minds of civil engineers, is that a leak is a thing that shows on the surface; and if it does not show on the surface it is not only out of sight, but also out of mind. There was a reason for this, years ago, when there were no large meters built for large pipes. That reason no longer exists. Such a meter has been in operation in a 9-ft. pipe, and there is nothing to hinder the same meter from working in a tunnel full of water—the Niagara tail-race tunnel, if you please. Such meters do not cost very much, and they have been in practical use for eight years. Anyone who has never tried a meter on a main and seen what it reveals to him, and the methods and helps it reveals to him in his business, has yet a great many pleasant experiences before him. It is just as easy to put a meter on a district of a city, or a whole city, now, as it has been for the last twenty or thirty years to put it on a single house. Those kinds of meters are the ones by the use of which it is possible to find leaks in broken mains and in service pipes, which latter, in the speaker's opinion, are the greater sinners of the two in the way of producing waste that does not show on the surface. It is the easiest thing in the world for a main to be broken completely and run a full stream of water and nobody know anything about it for days and months and years. There was a case of this kind in Cambridgeport, Mass., about twenty years ago. There the streets are very often built up of oyster shells—or used to be, when oysters were more plentiful than they are now—and one can readily see that the flow from a 6-in. pipe, under a moderate pressure, such as also was customary then, broken off in a dump made of oyster shells, would never show on the surface. Such a one was found, and it had been leaking nobody knew how long. Mr. Herschel.

It is the same with service pipes. The speaker had a little experience of that sort in his own yard. There is a barn about 150 ft. from his house, and an extraordinary consumption of water led to an investigation by the water company, which showed that the whole house supply could be shut off, but as long as the pipe leading to the barn was open, a large quantity of water—it amounted to about $36 a

Mr. Herschel. year—went in the direction of the barn all the time, as shown by a close observation of the meter. The flow through the meter was uniform, and yet no water had ever shown on the surface of the ground. The reason was that the pipe was like a sieve throughout its whole length; and the point to be brought out about this pipe—it was a galvanized iron pipe, had been down about 15 years—is, that had it not been for the meter, it never would have been possible to suspect or find the leak. This is a single case. Imagine, now, a city like New York, and managed in the same way—imagine the many service pipes there, which are probably doing the same thing, it being remembered that New York, for a very large part of its surface, is built on very coarse sand. Apply the lesson to almost any city, and it will teach the same thing.

The same example teaches another lesson. As many probably know, the last eleven years of the speaker's life have been spent in building up a wholesale dealer in water, called the East Jersey Water Company. It sells water to municipal corporations by the million gallons. It also sells water to what is called the Orange Water Company by the million gallons. The Orange Water Company did not believe in meters until they themselves bought by meter, and from the moment they bought by meter, it took no great time to show them that they would better sell by meter. It has worked the same way in Bayonne, N. J., and similarly in the City of Newark, which in spite of its great growth now consumes less water than it did four years ago. It will work the same way anywhere.

In this matter, the speaker believes in appealing to human nature, and letting the results work out for themselves; applying business principles to what is a business operation. The furnishing of water costs money to the furnisher or seller, and if he will deal with it as other commodities are dealt with, the lesson will spread to other consumers. Nothing else is necessary, certainly not at the present time, when the gross abuses must be dealt with first.

A discussion of this sort would be very incomplete without mention of the work that Mr. Bailey, of Albany, has done within a short time, the results of which were published in *Engineering News* of April 18th, 1901. It is no longer a subject for doubtful premises and of theoretical or of arithmetical consideration to say what American cities can do by metering water to the consumers. That question is settled, at least in its general outlines. Mr. Bailey procured the statistics of 137 American cities and found that the average consumption in these cities was 137 galls. per consumer per day, but once let 50% of the taps be metered, and this consumption reduces, on the average, to 62 galls. In Mr. Bailey's table the cities were given alphabetically, but in Table No. 2 twenty-four of these cities have been arranged in their order of least consumption per consumer.

TABLE No. 2.—TWENTY-FOUR AMERICAN CITIES, ARRANGED IN ORDER OF LEAST CONSUMPTION PER CONSUMER. Mr. Herschel.

No.	City.	Consumers, when known; otherwise population.	Taps.	Percentage of taps metered.	CONSUMPTION PER DAY.	
					Per tap.	Per consumer.
1	Woonsocket, R. I.	32 000	2 347	91.01	398	29
2	Brockton, Mass.	35 000	5 275	81.51	221	32
3	Fall River, Mass.	104 500	6 943	94.25	548	36
4	Sioux City, Iowa	33 111	3 000	50.83	476	43
5	Quincy, Ill.	36 252	2 700	48.15	611	46
6	Racine, Wis.	29 102	4 916	24.41	279	47
7	Lexington, Ky	26 369	1 500	99.47	833	47
8	Des Moines, Iowa	62 139	7 499	57.19	400	48
9	Malden, Mass.	33 664	6 426	45.67	265	50
10	Utica, N. Y.	56 383	7 064	96.80	425	53
11	Providence, R. I.	187 300	21 566	82.60	470	54
12	Topeka, Kan.	33 608	2 900	18.97	655	56
13	Lawrence, Mass.	57 200	5 926	74.01	541	56
14	Covington, Ky	42 938	5 300	78.30	472	58
15	Manchester, N. H.	56 987	5 500	67.27	636	61
16	Dayton, Ohio	85 333	12 000	46.67	442	62
17	Kansas City, Mo.	163 752	13 000	40.00	?	62
18	Peoria, Ill.	56 100	6 058	6.90	578	62
19	Taunton, Mass.	26 100	4 502	40.69	360	62
20	Newton, Mass.	32 800	7 087	84.68	294	64
21	Lynn, Mass.	73 000	12 577	19.88	370	64
22	St. Paul, Minn.	125 000	17 093	28.15	488	67
23	Worcester, Mass.	113 000	13 292	94.31	596	70
24	Salem, Mass.	35 700	6 400	2.81	390(?)	70

The average amounts to about 400 galls. per tap. Per consumer, it can be stated that it should be about 60. Anything that is not above 60 is fair, although in Providence, R. I., which compares very well with any city in the United States in general make-up, a city of 200 000 people, a manufacturing city with water-works more than 25 years in use, the consumption, it is believed, has never been 60 galls. from the beginning, certainly never for a long time or much over 60 galls , and is now 54 galls.

In the same way, in Table No. 3, twenty-four American cities are arranged in the order of greatest percentage of taps metered. Such a table, of course, is entirely different from Table No. 2, but is instructive. Bayonne, N. J., which stands at the head of this list, is a place of comparatively few inhabitants, and when works like those of the Standard Oil Company locate in such a place, they overslaugh the consumption by the inhabitants, and in this particular case, they produce a consumption fully 50% greater than if there were only the ordinary amount of manufacturing.

Mr. Herschel. TABLE No. 3.—TWENTY-FOUR AMERICAN CITIES, ARRANGED IN ORDER OF GREATEST PERCENTAGE OF TAPS METERED.

No.	City.	Consumers, when known, otherwise, population.	Taps.	Percentage of taps metered.	Consumption per Day. Per tap.	Consumption per Day. Per consumer.
1	Bayonne, N. J.	32 722	3 000	100.00	1 024	94
2	Lexington, Ky.	26 369	1 500	99.47	833	47
3	Yonkers, N. Y.	45 000	4 968	97.67	730	81
4	Utica, N. Y.	56 383	7 064	96.80	425	53
5	Worcester, Mass.	113 000	13 292	94.31	596	70
6	Fall River, Mass.	104 500	6 943	94.25	548	36
7	Atlanta, Ga.	65 000	9 275	91.64	587	84
8	Woonsocket, R. I.	32 000	2 347	91.01	398	29
9	Newton, Mass.	32 800	7 087	84.68	294	64
10	Providence, R. I.	187 300	21 566	82.60	470	54
11	Brockton, Mass.	35 000	5 275	81.51	221	32
12	Covington, Ky.	42 938	5 300	78.30	472	58
13	Atlantic City, N. J.	28 500	4 249	77.62	587(?)	80
14	Pawtucket, R. I.	80 000	8 293	76.80	799	82
15	Lawrence, Mass.	57 200	5 926	74.01	541	56
16	Milwaukee, Wis.	300 000	41 485	67 59	578	80
17	Manchester, N. H.	56 987	5 500	67.27	636	61
18	Des Moines, Iowa	62 139	7 499	57.19	400	48
19	Lincoln, Neb.	25 000	3 550	56.34	564	80
20	Fitchburg, Mass.	25 000	4 437	54.70	676	120
21	Lowell, Mass.	94 000	10 634	52.53	752	85
22	Sioux City, Iowa	33 111	3 000	50.83	476	43
23	Toledo, Ohio	65 384	11 888	50.26	652	119
24	Quincy, Ill.	36 252	2 700	48.15	611	46

In such a matter of statistics as indicated in these tables, it should be emphasized that it is numbers that tells. The statistics of 137 cities will yield a true lesson, even though a great many of those statistics may be found faulty. The number of them and the law of averages makes their resultant lesson true.

The speaker has had no such experience as Mr. Trautwine has recited. On the contrary, he knows that he has been the cause of several cities or companies introducing meters, simply by selling water to them by meter. That is all that is necessary. The principle involved is not one of science at all. There is nothing in it but human nature. The fact is, no individual or city knows or thinks what it is doing, or can know or think, until the water is measured, both coming in and going out, and to be successful the lesson must be made to appeal to the pocket. There has been a vast amount of nonsense spoken on the subject of meters as instruments of punishment, or as something cruel and unusual, and that the consumer should put the meter in or pay for it on a separate bill. These are notions in which we have grown up. Now, what is a meter? What is the proper object of a meter? Here are certain fixed charges that must be met. Let the season be hot or cold, rain or

shine, those fixed charges are going on, and have to be met at the end of the year. Who is to pay them? They should be equitably distributed among the beneficiaries. The cost of the water, at the service pipe of the consumer, let it be what it will—and ordinarily this will be from $50 to $100 per million gallons—should be equitably distributed among the consumers. A meter is nothing more than an instrument for accomplishing this object, and, in water-works operation, the question as to whether or not a meter should be put in should never have been raised. The meter should have been considered as part of the plant, just as much as a gas meter is a part of a gas plant or an electric meter part of an electric plant; and probably the question never would have come up, and all this discussion never would have been had, if water meters, as perfect as they are to-day, had originally been on hand. The speaker thinks that is the only reason, and that the time for any of those considerations has gone by. Large meters and small meters are now so well built—the ordinary house meter is a marvel of good construction, durability and cheapness—that the speaker does not think the question with regard to them would ever have arisen had they been available thirty years ago in their present shape, any more than it arose with regard to gas meters or electric meters; and the time for considering them as anything else than part of the plant has gone by. Mr. Herschel.

But the greatest benefit that the method herewith described, for enlisting the interest of every member of a community in the requisite struggle against waste of water, may confer on that community is to reduce enormously the cost of the water-works themselves, or of water-works extensions. The average city in the United States may thus postpone the necessity of an impending water-works extension some 10 years. In the case of a city known to the speaker, where the leakage was measured, it appeared that by gradually introducing consumers' meters and stopping street waste until the conditions now prevailing at Fall River, Mass., had been attained, that city could get along with its existing water supply for 51 years, notwithstanding its natural growth during that half century. On the other hand, if matters were allowed to proceed as hitherto, it would need water-works extensions within a year.

Speaking on the basis of an educated judgment in such matters, the speaker estimates that Buffalo could, merely by repression of waste of water, do without water-works extensions for 30 or 40 years; the Metropolitan District of Massachusetts, for 10 or 15 years; Cincinnati, for some 20 years; and in that proportion elsewhere in the United States. There is no reason whatever, except a neglect properly to attend to that branch of water-works administration here and now under consideration, that would necessarily make any one of the named cities consume more water *per capita* than, for example, Providence, R. I.

Mr. Brooks. FRED. BROOKS, M. Am. Soc. C. E. (by letter).—An example of small works in which meters have been successfully applied is at Reading, Mass., where the population is a little less than 5 000, the water has to be purified as well as pumped, and the capacity of the source is not greatly above present needs. About 800 meters were added, at a cost of nearly $10 000, with the result of bringing the year's expenses at the pumping station below those of a previous year, selected for fair comparison, by about $700. It was estimated, from the rate of increase in the demand for water before the meters were put in, that, without them, an additional force would have been required at the pumping station for 150 days in the year at $10 per day, amounting to $1 500, or about 15% of the cost of the additional meters. The particulars are given by Superintendent Lewis M. Bancroft, in the Tenth Annual Report of the Water Commissioners of the town, for the year ending December 31st, 1899.

Mr. Brackett. DEXTER BRACKETT, M. Am. Soc. C. E.—The point referred to by Mr. Kuichling, that the recorded consumption is often much greater than the actual quantity delivered to the mains, should be emphasized. The recorded consumption is in many cases calculated from the displacement of the plungers of the pumping engines, without making sufficient allowances for the slip or loss due to defective valves and worn plungers. When pumping machinery is new and in good order, the slip is not generally more than 2% of the theoretical discharge; but an engine which was operated for several months with a slip of nearly 50% came under the personal observation of the speaker, and it is probable that many cases exist to-day where the slip exceeds 10 per cent.

Quite a large percentage of the increase in the consumption of water may be attributed to the very great increase in the number of water fixtures *per capita*, as well as to the design of the fixtures now in general use.

Table No. 4, showing the number of fixtures in use in Boston for ten-year periods from 1870 to 1900, with the percentages of increases and the increase in population and consumption during the same periods, illustrates very forcibly the great increase in the conveniences offered for using and wasting water.

While the population has doubled, the number of water fixtures in use has increased 4½ times, and the water-closets, bath-tubs and wash-tubs have increased from 5½ to 11½ times the number thirty years ago. To-day, water fixtures are very much more generally used in the cheaper class of houses than in former years, and the fixtures used are very often of inferior quality, and for that reason soon become sources of waste.

There is often a tendency to consider all the increase *per capita* in consumption as preventable waste, but it must be remembered that

new uses for water are continually arising, and although the use may be a luxury rather than a necessity, it is one which the engineer must consider as legitimate. Mr. Brackett.

TABLE No. 4.

	1870.	Percentage of increase.	1880.	Percentage of increase.	1890.	Percentage of increase.	1900.	Percentage of increase, 30 years.
Taps and sinks.	70 009	50.4	105 309	38.6	145 943	38.	201 360	187.6
Bowls..............	25 652	86.9	47 946	39.2	66 725	58.6	105 839	312.6
Bath-tubs..........	9 811	85.7	18 220	83.5	33 431	110.9	70 521	618.8
Water-closets.......	28 227	102.9	57 278	74.1	99 731	57.7	157 320	457.3
Urinals.............	2 499	65.1	4 126	22.4	5 052	13.1	5 714	128.7
Wash-tubs..........	9 615	107.3	19 930	124.9	44 816	150.9	112 435	1 069.4
	145 813	73.4	252 809	56.5	395 698	65.1	653 189	348.0
Total population....	278 850	30.1	362 800	23.6	448 500	25.1	560 900	101.1
Daily average consumption (million gallons)...........	17.500	71.4	30.000	18.6	35.572	81.3	64.504	268.6
Fixtures *per capita*.	0.523	33.3	0.697	26.5	0.882	32.1	1.165	122.8
Consumption *per capita*............	62.758	31.7	82.7	— 4.1	79.31	45.0	115.00	83.3
Consumption per fixture	120.017	—1.1	118.7	—24.3	89.9	9.9	98.8	....

One or two facts will illustrate this point:

In Boston the consumption per inhabitant for six of the more important industrial uses in 1880 and 1890 is shown in Table No. 5, all of the water for these uses being metered:

TABLE No. 5.

	1880. Gallons.	1890. Gallons.
Steam railroads..........................	1.78	4.56
Sugar refineries..........................	0.74	1.13
Gas-works..........................	0.31	0.33
Electric light and power..........................	....	0.97
Breweries..........................	0.54	1.22
Elevators..........................	0.95	2.05
	4.32	10.26

This increase, of about 6 galls. *per capita* for a few purposes, is nearly one-fifth of the total *per capita* increase for the same period.

Again, if from the fifty cities of the United States having the largest population are selected those where more than 40% of the taps were metered in the year 1900, it is found that all but two of them show an increase in consumption *per capita* during the past ten years, although the use of meters has been largely increased.

Mr. Brackett. The speaker is of the opinion that the best method of preventing waste on the premises of the water taker is by applying water meters and charging water takers for the actual quantity used. The time may come when the suggestion of Mr. Kuichling, that water may not be supplied under any condition for certain purposes, may be carried out, but, so long as the present enormous waste continues, the speaker believes that the payment for water used, as determined by meter measurement, will sufficiently restrict the waste.

Although engineers and water-works officials are now almost, if not quite, unanimously in favor of furnishing water by meter measurement, the water takers in many cities have yet to learn that it is for their benefit to pay for the actual quantity of water used, and it is the province of the engineer to educate public opinion and to encourage he gradual introduction of meters, rather than to attempt to force their use upon an unwilling public.

TABLE No. 6.

	Percentage of Taps Metered.		Gallons per Capita Consumption.	
	1890.	1900	1890.	1900.
Fall River	74.6	94.3	31	36
Worcester	89.4	94.3	59	70
Atlanta	89.6	91.6	36	84
Providence	62.8	82.6	48	54
Milwaukee	31.9	67.6	110	80
Toledo	9.4	50.3	72	119
Lowell	22.9	52.5	66	85
Syracuse	14.6	47.3	68	102
Dayton	3.8	46.7	47	62
Nashville	0.8	41.5	146	140
Averages	40.0	66.8	68	83

Mr. Christian. G. L. Christian, Assoc. M. Am. Soc. C. E. (by letter).—For several years the writer resided in a house where the water was metered. The house contained nine persons, five of whom were adults and four were small children. The house had all the modern improvements, and stood on a lot 55 ft. wide and 100 ft. deep. There was a sewer in the street, and the water pressure was about 50 lbs. per square inch. All the laundry work was done in the house, and a hose was used to water the garden and lawn when necessary.

In the mornings, before any water was drawn for use, it was allowed to run long enough to allow the escape of the water which had stood in the house pipes all night, and in hot weather, before drawing any for drinking purposes, it was allowed to run until it was as cool as it would get. All the water needed was used, without considering

Mr. Christian.

the cost, as the water bill was paid by the owner of the house. Although it was used lavishly when needed, waste was curtailed to a minimum by having the plumbing fixtures always in good order, and not allowing the water to run all night in cold weather to avoid freezing, that not being necessary, as the plumbing was well protected and the house well built.

The writer became interested in the matter of the water consumed in the house, and, upon examining the records in the office of the Board of Water Commissioners, was surprised to learn that at no time during the previous three years did the consumption exceed 17 galls. *per capita*.

Substantially, all the water consumed in Yonkers, N. Y., is metered, and, according to the annual report of the Board of Water Commissioners for the year 1897, there passed through all the meters, for domestic use, 278 984 470 galls., or 22.07% of the water pumped, as measured by plunger displacement; which, divided by 34 000 —the estimated population using the water—gives 22.5 galls. *per capita*.

During the same year there passed through manufacturers' meters 26.83% of the water pumped—equal to about 27.5 galls. *per capita*—making 48.9% accounted for.

The annual report of the same Board, for the year 1900, with 45 000 estimated consumers, shows a *per capita* consumption of 25 galls. as passing through all meters, except those of the manufacturers, and the amount passing through the latter was equal to a consumption of 13.5 galls. *per capita*; the total amount passing through all meters being 48.12% of the amount pumped. The other 51.88% is partly accounted for by street sprinkling, construction work, flushing sewers, fire purposes, the unreliability of the method of measuring —which probably records a little more than is actually pumped— and last, but not least, loss from leaks in the mains and service pipes.

The city is quite a manufacturing center, there being employed in its industries probably about 8 000 operatives, of whom perhaps 25% are skilled mechanics.

It is the home of many people of wealth, and has many miles of beautiful streets lined with handsome residences and well-kept lawns, and a general air of prosperity pervades the city as a whole.

When it is more economical to restrict waste than to build new works or enlarge those already built, the writer agrees with Mr. Herschel that all water used should be measured—not only when it begins its journey through the principal main, but through its various travels—by districting the city and metering the water entering each district; and then, with a meter on every tap, the location of leaks could be detected, and those who used or wasted the water would pay for it.

Mr. Christian. It would seem that a supply furnishing 60 galls. *per capita* should be ample for municipalities which have no manufactures of moment, providing good plumbing is required, and no great amount of leakage is allowed in the mains or service pipes.

Mr. Crowell. Foster Crowell, M. Am. Soc. C. E. (by letter).—The writer is greatly interested in the subject of the proper allowance for consumption of water and the adoption of practical measures to reduce waste in public water supplies. With Mr. Desmond FitzGerald, he believes in taking every reasonable step to stop needless waste. His own investigations lead him to endorse thoroughly what Mr. Trautwine has stated, both as regards the enormous extent of waste now going on in our principal cities and the apparent hopelessness of reaching the public ear and mind in the effort to educate the community in this respect.

In 1900 the Engineering Committee of the Merchants' Association of New York, of which the late Thomas C. Clarke, Past-President, Am. Soc. C. E., was Chairman, requested the writer to investigate and report upon the use and waste of water in the Boroughs of Manhattan and the Bronx in New York City.* In pursuit of that duty he had sought and obtained many facts relating to the supplies of water actually consumed in various cities, a comparison of which convinced him of the fallacy of the reasoning that is so often heard, that because a city is rich and prosperous, therefore it will, on that account, naturally and properly need a larger *per capita* supply than smaller places.

It is true that among individual consumers it is almost invariably found that in the houses of the wealthier class there is a very much greater use than in the houses of the poorer class, and that, as the standard of living is raised from decade to decade more or less in every class of people, the legitimate average *per capita* water consumption also increases; yet he differs from the general conclusion, believing that, of the class using water lavishly, the proportion may actually be smaller in the large city than in the small manufacturing town. An unsuccessful effort has been made to determine the actual proportions of wage earners to total population in several cities, for comparison. The figures of the United States census of 1900, which might throw light on this contention, are not yet available, and those of 1890 are of little service at this date, especially as a form of classification which would bring out clearly the point in question has not been used.

In the absence of statistics we can only fall back upon conjecture aided by analogy, and as New York, for instance, is the largest, or one of the largest, manufacturing centers in the world, is said to

*"An Inquiry into the Conditions Relating to the Water Supply of the City of New York," by the Merchants' Association of New York, August, 1900, page 187, "The Use and Waste of Water in New York City," by Foster Crowell, M. Am. Soc. C. E.

contain more wage earners and to have a far denser population than Mr. Crowell. any other city of civilization, it cannot be admitted that it is a city of wealth and luxury, in the sense in which the term has been used in this discussion.

The same is true, in a measure, of Philadelphia, though not to the same extent, so that it would be reasonable to expect a somewhat higher average *per capita* consumption there than in New York, while in Washington we should expect to find a much higher figure. The comparisons in the report referred to, containing the evidence from Fall River, Woonsocket, etc., with the observed facts relating to water consumption in New York and Philadelphia, to which use of such figures Mr. Hering appears to object, were for the purpose of directing attention to the enormous difference in the quantities of water consumed in metered and unmetered cities, as illustrated by those cases. Here, it is important to revert to the fact that lavish use is not necessarily waste, and this should be emphasized, because the confusion between these terms does not appear to be confined to laymen, but seems to exist also in the quarter where we should least expect it, the minds of many engineers.

It is also well to understand clearly what is meant by the term "*per capita*," which is only used here because it is a term of convenience. It is used variously, and generally loosely. Here, it is meant to indicate the proportional part of the water supply that is represented by each individual in the entire population served with water from a given supply, and including all the water used, for whatever purposes.

The writer takes exception to Mr. Hering's proposition, that meters should be omitted in houses for small families on the ground of economy. Because it may cost less to let a certain amount of water go to waste than to provide means for checking it is no argument when the community is largely made up of small families, especially as there is no likelihood that under such conditions, either the wastage or the use would be limited to the certain amount. In the writer's judgment the use of meters should be universal and uniform; they should be owned by the city, or water company, in all cases. In cases where the supply is by the city, a certain small fixed allowance should not be charged for, though measured and taken account of. Beyond that, the meter charges should apply to all water consumed, on a rate schedule decreasing as the quantity consumed increases.

The writer would join with others in their protest against that ancient fraud, the dictum that "water should be free as air." It cannot, in the nature of things, be made free, *ergo* its cost should be reduced to the minimum. The way to do that is to make the supply go as far as possible.

Even where the public water supply is copious and need not be

Mr. Crowell. stinted, the wasting of it should not be tolerated. In the nursery we were taught that "wilful waste makes woeful want," and we should not lose sight of the fact that the less water we waste, the more we can use at the same cost, or the less that which we do use will cost us.

It makes no difference, in principle, whether wastage is due to defects in the distribution system or carelessness by users; in either case, or in both cases, it should be stopped. The latter case is the easier to deal with, for, upon the introduction of meters, as the writer has elsewhere stated:

"Every householder would thereupon become directly interested in the reduction of the waste, and the inherent trait of human nature which previously had led him to consider that the more water he used the more value he was getting back from his taxes, would now cause him to feel concerned lest he should suffer by being made to pay for water he did not use. That is the experience in other places where meters have been universally applied, and to a greater or less extent is to be counted upon."

Mr. FitzGerald's shining example is a case in point.

It is unfortunately true that in several prominent instances engineers of high authority, after pointing out the probability that tremendous waste was going on, lacked the courage of their convictions, and, instead of urging the adoption of radical means for its stoppage, advised that sources for additional supply should be provided, thereby increasing the opportunity for waste.

Undoubtedly, the legitimate uses of water will increase, both in quantity and in kind, faster than the increase of population. It would seem, therefore, right and prudent for every city to make some provision in advance for the supply of the future, even extending to the purchase of water-sheds and reservoir sites if need be, but further expenditure for new water-works is not justifiable until the point is reached where the legitimate use approaches the working supply, with a reasonable margin of time for their preparation.

Mr. Sherman. CHARLES W. SHERMAN, Assoc. M. Am. Soc. C. E. (by letter).—The writer has recently compiled a series of tables,* containing more or less complete statistics relating to the water-works of sixty-one cities and towns, for the year 1900. From these statistics Table No. 7 has been prepared. This table gives statistics relating to the consumption of water and use of meters in forty cities and towns, these being all for which sufficient data of this kind were available.

A part of this information is reproduced in the diagram, Fig. 4, which shows for each town the relation between the *per capita* consumption of water (per consumer where given, otherwise per inhabitant) and the percentage of services metered.

* Published in the *Journal* of the New England Water-Works Association, for September, 1901.

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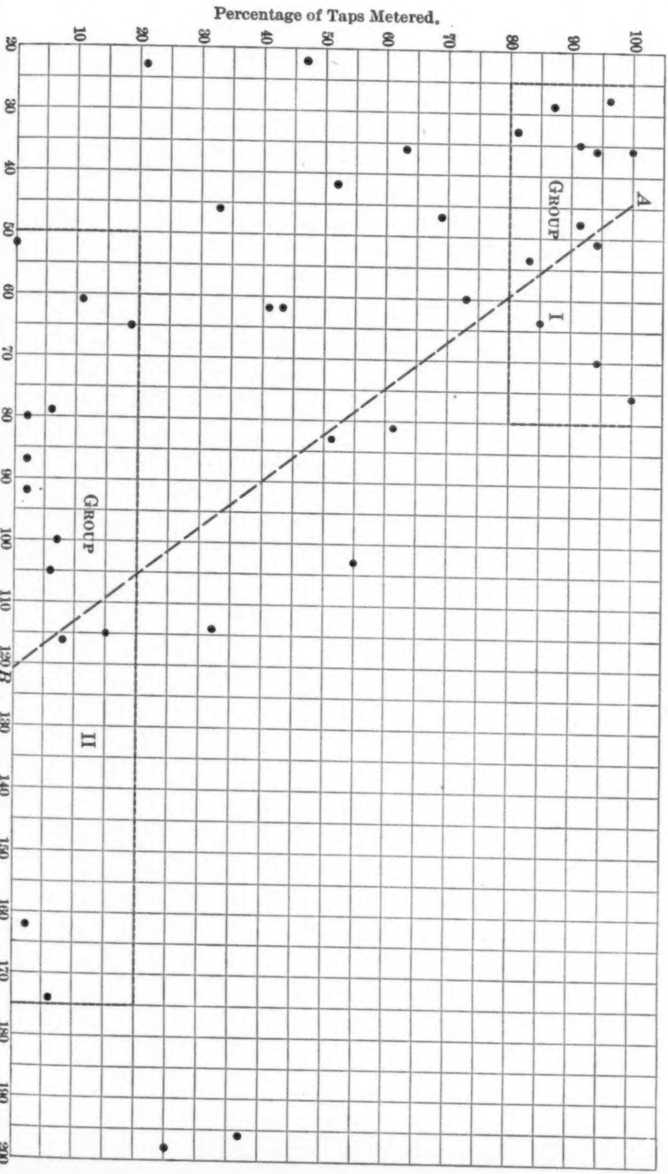

Fig. 4.

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From the forty points on the diagram two groups have been selected. Group I includes all the places, twelve in number, having more than 80% of the services metered. It will be noted that the range of consumption for this group is from 28 to 76, or 48 galls. per head per day. Group II includes the 13 places having less than 20% of their taps metered, and in this group the range of consumption is from 52 to 174, or 122 galls. per head per day. Taking, as mean consumption for each group, the average between the highest and lowest consumption in that group, and plotting these figures as corresponding to 90 and 10% of services metered, respectively, points are obtained through which the line A B has been drawn.

TABLE No. 7.—Consumption and Use of Water in Forty American Cities and Towns.

City or Town.	Population, 1900.	Consumers, 1900.	Average Consumption of Water, Gallons per Day.		Percentage of total consumption metered.	Percentage of taps metered.	Percentage of receipts from metered water.
			Per inhabitant.	Per consumer.			
Andover, Mass	6 813	....	60	....	....	73	....
Bay City, Mich	28 000	16 000	112	196	21	37	....
Billerica, Mass	2 780	1 230	20	46	....	33	19
Brockton, Mass	40 063	35 000	29	33	51	81	87
Burlington, Vt	18 800	18 100	46	47	53	69	77
Cambridge, Mass	91 886	....	79	....	....	6	....
Chelsea, Mass	34 000	34 000	87	87	12	2	....
Erie, Pa	52 733	....	162	....	....	2	18
Fall River, Mass	107 623	104 523	35	36	....	94	....
Fitchburg, Mass	31 531	27 000	....	103	....	55	67
Geneva, N. Y.	11 000	....	81	....	24	61	....
Haverhill, Mass	37 175	....	61	....	....	11	....
Holyoke, Mass	46 204	45 204	103	105	14	6	17
Ipswich, Mass	4 658	....	23	....	....	21	....
Keene, N. H	9 300	8 000	150	174	....	6	....
Lowell, Mass	95 000	....	83	....	....	51	....
Lynn, Mass	73 600	72 128	....	65	20	19	....
Madison, Wis	19 164	16 548	44	51	....	94	....
Marlboro, Mass	13 609	11 726	36	42	....	52	....
Metropolitan W. W., Mass	815 400	....	116	....	....	8	....
Middleboro, Mass	....	3 750	56	62	48	43	66
Minneapolis, Minn	202 718	95 000	93	198	19	25	....
Nantucket, Mass	3 002	2 400	42	52	....	0	....
New Bedford, Mass	62 500	55 000	101	115	23	15	....
New London, Conn	17 500	15 800	91	100	....	7	....
Newton, Mass	33 587	32 800	62	64	55	85	86
Oberlin, Ohio	4 800	2 800	21	36	43	63	....
Providence, R. I	187 297	187 297	54	54	60	83	....
Reading, Mass	4 969	4 200	30	35	....	91	....
Springfield, Mass	62 059	48 200	88	114	21	32	31
Taunton, Mass	31 006	26 116	53	62	37	41	....
Waltham, Mass	23 700	23 250	90	92	5	2	....
Ware, Mass	8 263	....	36	....	56	100	79
Wellesley, Mass	5 072	4 929	47	48	53	91	....
Whitman, Mass	6 172	....	22	....	....	47	63
Winchendon, Mass	5 001	....	12	28	47	96	....
Woburn, Mass	14 254	....	80	....	10	2	....
Woonsocket, R. I	32 500	32 000	28	29	....	87	....
Worcester, Mass	118 421	113 217	....	70	52	94	....
Yonkers, N. Y	....	....	76	....	48	100	....

Mr. Sherman.

Judging from these figures alone, it would seem that this line marks a fair limit, beyond which consumption (including waste) may justly be considered excessive. This line would give, for normal consumption, 44.5 galls. per head daily with all services metered, and 121 galls. where no meters are used. Of course, generalizations of this kind are of very limited application, and must be used only with the greatest caution.

The statistics of Woonsocket, Fall River, Brockton, and other places are frequently quoted as showing that a consumption (including waste) in excess of 35 galls. per head daily is excessive, and, by the use of meters, could, perhaps, be reduced to that amount. The writer believes that argument to be ill chosen, as all the cities named are manufacturing centers, containing a large percentage of operatives' houses or tenements, in which there are few fixtures and in which the use of water is restricted. In his opinion, the smallest quantity of water which will be consumed in dwellings of a high class, where the plumbing is carefully looked after and leaks are promptly repaired, will be, generally, not less than 35 galls. per head per day, and the average quantity used in such houses will be more nearly 45 galls. per head per day. The average domestic use in a city containing all classes of houses in ordinary proportions would then probably not be less than 30 galls. per head per day, to which must be added the quantity used for fires and other public purposes and the leaks in mains and services, in order to obtain the total consumption (including waste).

This opinion regarding the legitimate use of water is based on actual observations. For the past year the writer has taken readings of the water meter in his house, at intervals of about a week, and has taken great care to have no leaky fixtures and to reduce as far as feasible the unreasonable drawing of water, without curtailing its proper use. His records show the average use of water in that time to be at the rate of 31.5 galls. per head per day, the weekly average ranging from 21.2 in November to 47.8 galls. in July. A friend, similarly situated, has furnished records showing that in his house, where the use of water is somewhat lavish, but where leaks are not tolerated, the consumption has averaged 47.2 galls. per head per day for the past three years, the yearly averages being 49.5, 45.4 and 46.7 galls., respectively.

Other interesting deductions can be made from such data as are given in Table No. 7. For instance, if the percentage of receipts from metered water is very nearly the same as the percentage of taps metered, the inference would be that the unmetered consumers were not making an excessive use of water, and that little, if any, reduction of consumption (including waste) would result from extending the use of meters. In case, however, a large percentage of the total consumption is used by a few consumers, through meters, this deduction may

Mr. Sherman. not be warranted. Again, in cases where 90 to 100% of the taps are metered, if only 50 or 60% of the consumption is accounted for by meters, then the loss from leakage, or the public use of water, or both, must be very great.

Mr. Kuichling. E. KUICHLING, M. Am. Soc. C. E. (by letter).—Several points of interest have been brought out in this discussion, although the principal feature seems to be the unanimity with respect to the desirability of applying meters to service pipes. By this agreement a very important step in the advancement of water-works practice may be regarded as having been taken. There is, however, a noticeable tendency to consider the meter as the chief agency in preventing waste, and to regard legitimate use as "everything that the consumer chooses to pay for." The writer does not believe that this proposition is tenable without the vital qualification that such use shall always be reasonable; and the determination of reasonable allowance for different classes of consumers appears to him to be eminently desirable in the premises.

It has been said that shrewd manufacturers do not require to be taught how to get their water supply from the community for the least money, with the implication that they are the best judges of their own needs. While this may be true in some instances, it cannot be accepted as a general statement, inasmuch as enormous differences in consumption, in establishments of equal producing capacity, are encountered on every side, and the only coincidence of judgment seems to be to have a great abundance of water at hand. Demands for service pipes of unnecessary and preposterous magnitude are made so often that it is a conspicuous exception to meet an applicant who can justify his estimate. For this reason the water-works superintendent should know the necessities of the different consumers, and be able to adapt the size of the service pipes thereto in a rational manner. Especially is this the case when the water supply of a city has reached its limit, and it becomes imperative either to prevent useless consumption or to provide new works at large expense.

The exercise of sound knowledge of trade requirements in preventing waste cannot properly be characterized as "paternalism" in municipal government or water-works administration, and no officer should be deterred by the sight or sound of the objectionable phrase from acquiring and applying such knowledge for the ultimate benefit of the community or corporation he serves. By so doing he will make his position much more acceptable to the public, and far less mechanical to himself. The same remark is equally pertinent when meters are used, as the limitations of such measuring devices must be fully understood by an efficient officer. Several references to this point have been made in the discussion, and to emphasize it somewhat more strongly, the following instance in the writer's experience is cited.

Mr. Kuichling.

One of the largest water consumers in the City of Rochester, N. Y., obtained his supply through a 4-in. pipe and a 4-in. meter, and for several years the monthly consumption was fairly uniform. It then decreased abruptly in great degree, and on inquiring for the reason the answer was given that water was taken from another source. The meter was tested in place under relatively large flow, and found to give a registration of about 85% of the observed discharge into a capacious tank. Further investigation disclosed the fact that the employees of the consumer were still using the city water as freely as before, and that therefore the consumption should be about the same, also that the water was delivered into large tanks almost continuously in a stream of moderate size without appreciable registration. An accurate new meter was then substituted for the old one, with the result that the registration promptly returned to its former magnitude. On examining the old meter it was found that, owing to wear of parts, registration of discharge occurred only at large flows, as aforesaid.

The foregoing is only one of many similar cases, in the writer's experience, which indicate that the indiscriminate use of meters is not an infallible remedy for the prevention of waste, and that a water-works superintendent should possess a fairly good knowledge of a consumer's legitimate use of water, as well as of the various ills to which his own measuring devices are subject. In these directions there is still room for many valuable additions to our stock of information, and it is hoped that in future discussions such may be elicited.

By some writers, much stress is laid upon average figures of water consumption, apparently without reference to local trade or manufacturing conditions. Such figures are often illusory, however, when applied to a particular case, and, when covering a very large population, can be accepted only as a measure of domestic use. Thus, from Mr. Brackett's valuable contribution, it is learned that while the total average daily consumption *per capita* in Boston in 1880 was 82.7 galls., the use of water by six of the more important industries in that city amounted to only 4.3 galls. *per capita* during the same year; and that in 1890 the figures were 79.3 and 10.3 galls. *per capita*, respectively. Similar low proportions are found in other large manufacturing cities, although in some smaller towns the ratio is much higher. With the more extensive use of meters in our country, such data are gradually becoming available, and in time we may look forward to a much better presentation of this part of the subject than is now possible.

Those who are interested in average values of *per capita* water consumption will find some useful material in a table compiled by Allen Hazen, M. Am. Soc. C. E., from a "Report of the London County Council."* This table gives the population and use of water in 36

* Published in *Engineering News*, February 16th, 1899, p. 111.

Mr. Kuichling. English provincial municipalities for the years 1896 and 1897, but does not include London. The figures of consumption are all expressed in United States gallons.

Arranged according to population, the list would begin with Manchester, having a population of 899 093, and an average daily water consumption of 40 galls. per head, and end with Gloucester, having a population of 43 000, and an average daily consumption of 21 galls. per head. According to consumption, Middlesborough would head the list with an average of 61 galls. per head, while Wigan would end it with only 20 galls. per head per day. The total population in the 36 cities considered is 7 145 669, and the aggregate daily consumption is 238 174 154 galls., giving an average of 33 galls. per head per day.

A somewhat more extensive compilation* of similar character was made by the writer three years ago. All data were obtained from the best available sources at the time. The general results obtained are as follows:

In 100 American cities of 30 000 inhabitants and upward, representing a total population of 16 582 100, the average daily consumption was 112 galls. *per capita;* in cities of 1 000 000 inhabitants and over, it was 116 galls.; in cities of from 600 000 to 300 000 inhabitants, it was 122 galls.; in cities of from 300 000 to 100 000 inhabitants, it was 106 galls.; in cities of from 100 000 to 50 000 inhabitants, it was 105 galls.; and in cities of from 50 000 to 30 000 inhabitants, it was also 105 galls. The total quantity of water consumed per day by said 100 cities was 1 863 248 300 galls.

In 43 English, Scotch and Irish cities, ranging from 2 800 to 4 263 300 inhabitants, representing a total population of 9 616 400, the average daily consumption was 37.3 galls. *per capita.*

In 66 German cities, ranging from 16 400 to 1 122 300 inhabitants, representing a total population of 5 806 300, the average daily consumption was 21.2 galls. *per capita* in 1884, while in 1896 it was 23.8 galls. for an aggregate population of 3 352 400 in 14 large cities.

In 20 French cities, ranging from 4 130 to 2 269 023 inhabitants, representing a total population of 3 677 286, the average daily consumption was 59 galls. *per capita* in 1887.

In 12 Italian cities, ranging from 24 200 to 530 900 inhabitants, representing a total population of 2 533 600, the average daily consumption was 67.6 galls. *per capita* in 1892.

In 23 Spanish, Belgian, Dutch, Scandinavian, Russian, Austrian, Swiss and other European cities, ranging from 23 300 to 929 100 inhabitants, with an aggregate population of 5 590 300, the average daily consumption was 23.8 galls. in 1883.

In 12 Indian, Australian, Egyptian and South American cities,

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* Published in the *Transactions* of the Association of Civil Engineers of Cornell University, for 1898.

ranging from 30 000 to 773 200 inhabitants, representing a total population of 2 884 900, the average daily consumption was 23.4 galls. *per capita* in 1883. Mr. Kuichling.

TABLE No. 8.—STATISTICS OF WATER SUPPLY OF FORTY-THREE GERMAN CITIES OF OVER 50 000 INHABITANTS. ABSTRACTED FROM "STATISTISCHE ZUSAMMENSTELLUNG DER BETRIEBSERGEBNISSE VON WASSERWERKE," COLOGNE, 1899.

Number.	City.	For fiscal year.	Estimated population.	Average daily consumption, U. S. gallons, per day.	Percentage of Average Daily Consumption.			Consumption, in U.S. Gallons, per Head, per Day.	
					Metered.	Estimated.	Not accounted for.	Maximum.	Average.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	I.—SUPPLY OBTAINED BY PUMPING.								
1	Berlin	1896-7	1 763 049	36 300 000	84.6	4.2	11.2	30.4	20.6
2	Gelsenkirchen and vicinity	1897	573 000	16 600 000	93.4	4.4	2.2	......	28.9
3	Charlottenburg and vicinity	1897-8	430 320	7 270 000	85.1	....	....	34.0	17.0
4	Dresden	1897	352 700	8 750 000	65.1	34.8	0.1	39.2	24.9
5	Hanover	1897-8	272 000	4 640 000	74.6	8.4	17.0	*32.3	*22.7
6	Magdeburg	1896-7	222 238	5 690 000	82.6	5.4	12.0	33.0	25.6
7	Dusseldorf	1897-8	205 300	4 960 000	66.9	28.1	5.0	38.4	24.0
8	Königsberg	1897-8	178 000	3 130 000	50.0	49.9	0.1	29.6	17.4
9	Stuttgart	1897-8	166 798	4 120 000	38.6	42.0	9.4	44.0	24.6
10	Elberfeld	1897-8	158 000	6 270 000	64.4	30.4	5.2	51.2	39.7
11	Stettin	1897-8	150 000	2 800 000	84.0	2.3	13.7	28.5	18.7
12	Zurich	1896-7	145 000	6 690 000	48.4	46.2	5.4	68.0	46.0
13	Aachen	1897-8	138 523	2 540 000	75.6	3.2	21.2	24.3	18.2
14	Barmen	1897-8	138 000	6 280 000	32.0	58.0	10.0	63.5	45.3
15	Halle	1897-8	123 500	2 620 000	80.5	2.5	17.0	31.4	21.2
16	Strassburg	1897-8	117 500	2 490 000	52.8	27.7	9.5	38.5	21.2
17	Krefeld	1897-8	108 253	3 360 000	25.7	52.3	22.0	51.2	30.9
18	Brunn	1897-8	102 509	3 270 000	31.5	56.5	12.0	45.5	31.7
19	Mannheim	1897	100 000	2 090 000	72.7	18.1	9.2	36.2	20.9
20	Kiel	1897-8	90 000	1 570 000	68.2	20.9	10.9	25.4	17.5
21	Mulheim	1897	82 910	1 910 000	45.8	52.3	1.9	32.8	23.0
22	Geneva	1897	80 000	32 100 000	19.0	55.5	25.5	510.0	400.0
23	Erfurt	1897-8	80 723	1 110 000	80.0	13.8	6.2	......	13.8
24	Mainz	1897-8	78 000	985 000	93.4	1.8	4.8	21.4	12.6
25	Posen	1897-8	75 000	986 000	79.6	0.1	20.3	20.6	13.2
26	Würzburg	1897	71 000	4 030 000	5.5	88.4	6.1	58.3	56.9
27	Bonn-Godesberg	1897	69 000	1 800 000	50.8	48.4	0.8	47.0	25.9
28	Pressburg	1897	64 000	552 000	90.0	0.0	10.0	14.3	8.7
29	Darmstadt	1897-8	63 900	1 315 000	86.3	7.9	5.8	36.7	20.3
30	Hagen	1897-8	63 000	2 650 000	36.8	53.6	9.6	56.9	42.0
31	Gladbach	1897-8	60 963	980 000	59.2	30.9	9.9	28.5	16.1
32	Münster	1897-8	59 700	1 590 000	56.0	34.0	10.0	49.2	26.7
33	Potsdam	1897-8	58 355	735 000	93.9	1.3	4.8	25.3	12.7
34	Rostock	1897-8	50 100	1 720 000	26.5	71.3	2.2	52.0	34.0
35	Furth	1897	50 000	698 000	72.8	15.0	12.2	23.8	14.0
	Totals and averages	......	6 541 341	184 601 000	59.9	....	....	......	28.2
	Totals and averages, exclusive of Charlottenburg	......	6 111 021	177 331 000	58.9	29.5	11.6	......	29.0
	Totals and averages, exclusive of Charlottenburg and Geneva	......	6 031 021	145 231 000	67.7	23.8	8.5	......	24.1

* Includes river-water supply.

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TABLE No. 8—(*Continued*).

Number.	City.	For fiscal year.	Estimated population.	Average daily consumption, U. S. gallons per day.	Percentage of Average Daily Consumption.			Consumption, in U.S. Gallons, per Head, per Day.	
					Metered.	Estimated.	Not accounted for.	Maximum.	Average.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	II.—Supply Obtained by Gravity.								
36	Munich	1897	424 000	20 700 000	83.1	....	....	......	48.6
37	Nürnberg	1897	177 000	3 640 000	62.5	17.9	19.6	29.5	20.2
38	Danzig	1897	135 000	2 850 000	50.5	28.3	21.2	......	21.2
39	Basel	1897	96 000	3 790 000	75.2	1.5	23.3	55.0	39.4
40	Weisbaden	1897–8	77 000	1 930 000	68.9	26.9	4.2	38.0	24.9
41	Plauen	1897	60 000	513 000	84.8	12.9	2.3	......	8.4
42	Freiburg	1897	55 500	3 930 000	35.1	51.9	13.0	78.0	71.0
43	Metz	1897–8	55 300	1 800 000	11.7	60.3	28.0	40.0	32.5
	Totals and averages, Nos. 36–43, inclusive	......	1 079 800	39 153 000	69.3	....	....	......	36.3
	Totals and averages, Nos. 37–43, inclusive	......	655 800	18 453 000	53.7	28.4	17.9	......	28.1
	Totals and averages, Nos. 1–43, inclusive	......	7 621 141	223 754 000	61.6	....	....	......	29.4
	Totals and averages, exclusive of Nos. 3 and 36	......	6 766 821	195 784 000	58.5	29.3	12.2	......	28.9
	Totals and averages, exclusive of Nos. 3, 22 and 36	......	6 686 821	163 684 000	66.2	24.2	9.6	......	24.5

In the 176 European and other foreign cities mentioned above, the total population was 30 108 800, and the average daily consumption was 35.6 galls. *per capita;* and combining these figures with those relating to the said 100 American cities, will give a total of 46 690 900 inhabitants, consuming on the average 62.8 galls. of water per head per day. The figures also indicate that the consumption in the American cities is about three times greater than that in the European cities.

With respect to the influence of meters in reducing consumption or waste, little need be added to the excellent statistical work performed by Messrs. George I. Bailey and Charles W. Sherman. To supplement the same, however, Table No. 8, relating to 43 German cities, wherein meters are used more or less extensively, is submitted as a matter of interest. This table was compiled by Allen Hazen, M. Am. Soc. C. E., and the writer, from the official "Report of the German Association of Water-Works Managers" for 1899, and needs no further explanation than is given by the column headings. It may also be added that the original statistics mentioned are in great detail, and their form is commended for use by similar associations in other parts of the world.

Mr. Kuichling.

According to Table No. 8 the average consumption in the 43 cities specified is 29.4 galls. per head per day for an aggregate population of 7 621 141, and of this quantity 61.6%, on the average, is metered. It is also very interesting to examine the figures given in Columns 7 and 8, relating to the percentages of the supply which are respectively estimated and not accounted for. In the former the range is from 0.0 to 88.4%, with an average of 29.3%; while in the latter the range is from 0.1 to 28.0%, with an average of 12.2% for 41 cities. Those who have had charge of the water supply of a city of 50 000 or more inhabitants in our own country will doubtless look with much suspicion upon the accuracy of so small an amount as 0.1% unaccounted for when 49.9% is estimated, as in the case of Königsberg—No. 8 in the list. Nevertheless, the figures taken collectively are instructive, inasmuch as they indicate that the officers in charge of German water-works have adopted a closer system of accounting for the water distributed by them than their American brethren.

It may also be remarked that in many German cities manufacturers who use large quantities of water in their business generally provide themselves with an independent supply, so that the figures given in Table No. 8 relate mainly to the domestic consumption and the quantity used for general public purposes. Furthermore, the number of faucets and water fixtures in the buildings is generally much smaller than in the corresponding classes of American houses, whereby the waste or leakage is proportionally reduced.

The quantity not accounted for may perhaps be taken as the leakage of the distributing system and the "slip" of the meters. In this event, the very low percentages given in a number of cases are probably erroneous, as neither their meters nor their methods of laying pipes are materially better than our own; and if the loss in extensively metered American cities cannot be kept within a limit of 10%, it is fair to infer that a similar loss will prevail elsewhere. On this point, however, adequate data are still lacking, and it is hoped that such will be supplied by water-works officers in the near future.